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A METHODOLOGY FOR SETTING PRIORITIES AMONG POTENTIAL HOSPITAL INFORMATION SYSTEM APPLICATIONS

A THESIS

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SUMMARY

The general purpose of this research was to develop a methodology for determining implementation priorities among candidate applications to a real-time, patient-oriented hospital information system (HIS). The following specific objectives were established:

1. The development of a general planning approach to setting HIS priorities.
2. The establishment of guidelines and procedures for the development of scoring models to evaluate the improvement in effectiveness offered by candidate HIS applications.
3. The development and use of a scoring model to establish HIS priorities for a mock hospital as a demonstration of the general methodology.
4. An evaluation of the applicability of the methodology to HIS priority determination.
5. The identification of promising and important areas of the HIS priority planning process which are appropriate for additional research.

Primary emphasis in this research was placed on the scoring model development and cost/effectiveness analysis portions of the general approach. Guidelines and procedures were described for the development of customized scoring models for individual hospitals planning HIS implementation. These guidelines were then demonstrated and further explained through their use in the development of a

scoring model for a mock hospital. Members of an HIS planning team at the Medical College of Georgia actively participated in the methodology's demonstration and provided an evaluation of the benefits to be obtained from the approach as well as its general applicability.

Finally, the investigation, demonstration, and evaluation of the scoring model approach to setting HIS priorities led to the identification of promising and important areas of the HIS planning process which require further research and development.

CHAPTER I

INTRODUCTION

The general purpose of this study is to develop a methodology for determining implementation priorities among candidate applications to a real-time, patient-oriented hospital information system. As used herein, the term "hospital information system" (HIS) generally means a system that uses electronic data processing equipment and control procedures to provide direct on-line processing with real-time responses for patient information within the hospital or health care facility. The terms "real-time" and "patient-oriented" refer to the availability of a computerized multi-purpose patient record which can be recalled or updated almost instantaneously from remote terminals located throughout the hospital. The priority setting methodology developed in the research is based upon the use of a multi-criterion scoring model which allows the complex HIS evaluation problem to be systematically simplified into its elemental determinants.

The author's interest in the subject stemmed initially from involvement with rather crude scoring models for establishing priorities in other areas of health care planning and from a perception of their possible applicability in the complex HIS planning process. These interests were spawned and developed while the author was involved in information system planning activities for the United States Public Health Service in Rockville, Maryland. Experience in these activities revealed a need for a more systematic approach to HIS planning, but it also made clear the complexities, difficulties, and enormous scope which are involved. Furthermore, a review of the literature indicated that computer-based hospital information systems are rapidly approaching the point of economic and performance feasibility. The number and variety of individual HIS applications currently being developed cover virtually every aspect of hospital operation. Most long-range HIS concepts reported require that all information subsystems be eventually integrated to realize a hospital-wide computer-based information system. Because of the multiplicity of potential applications, the complexity of their interactions, and the limited resources available for HIS development, attempts to develop and implement a total hospital information system, covering all feasible computer-based applications within a single phase have been abandoned for a more gradual phasing of HIS development within an overall plan and schedule of implementation. With the increasing efforts of health care institutions to formulate HIS master plans to coordinate a modular implementation approach, a need is arising for the establishment of sensible priorities among various candidate HIS applications. This research should help such institutions in meeting that need.

The methodology developed herein relates the problem of setting such priorities to an overall HIS planning approach. This establishes an environment in which scoring model evaluation may be appropriately used. Procedures and guidelines for the design and use of HIS scoring models are described within this overall setting and are demonstrated by an example application of the methodology in a mock HIS planning situation. The demonstration of the scoring model design and application in evaluating specific HIS alternatives for this mock hospital was accomplished primarily by members of an HIS planning team at the Medical College of Georgia. The model design activities undertaken in the methodology demonstration and the analysis of the corresponding results provide further guidelines and examples for other HIS planners to review.

Because the role of information handling in hospitals has been estimated to consume up to 40 per cent of the total cost of hospital operations, and to hold commensurate importance in health care delivery, efforts to improve both the effectiveness and efficiency of information activities through the development of computer-based hospital information systems seem well justified. Unfortunately, many such efforts, despite substantial funding and support, have met with only limited success in accomplishing their proposed objectives. The developed methodology should aid future HIS efforts in two ways. First, its use should provide a logical method for determining a near optimal implementation schedule. Such a schedule would allow the early implementation of the candidate applications having the lowest cost/effectiveness ratios. In addition, because the scoring model technique allows representatives from diverse areas of the hospital to participate in the priority setting process, its use may serve to obtain a planning consensus over the entire hospital organization, therefore gaining support and cooperation for the implementation plans and improving the chances of success for the overall HIS effort.

Although the primary focus of this research is on the solution of the HIS priority problem, many of the considerations developed and described in the methodology represent innovations in the use of scoring models which are applicable to many other evaluation problems. Recent research which explores the effects of scoring model structure and design on evaluation results has been employed and expanded in establishing the guidelines proposed for model development and in analyzing the results of the methodology demonstration. These scoring model innovations and their application to the HIS priority problem should provide a significant contribution to both the future planning of HIS activities and the refinement of the scoring model as a useful evaluation tool.

CHAPTER II

SURVEY OF RELATED LITERATURE

Introduction

A review of the literature in the health field indicates a wide interest in real-time hospital information systems appearing in the early 1960's and increasing rapidly throughout the decade. Studies determining the high cost of information in hospitals were reported in the literature and used as justification for scores of extensive developmental and pilot study programs to implement real-time HIS systems. The literature gives considerable emphasis to reporting the general description of individual projects, past problems encountered, and future expectations of HIS development. These writings give an overall view of HIS activities to the general reader, but are notably lacking in providing planning and evaluation aids to prospective users of real-time systems. To some extent the importance of priorities within an HIS system has been identified in the literature; however, little guidance regarding how HIS priorities should be set has been offered.

The HIS priority setting problem does, however, have similarities with priority problems in other areas of the health field which have been approached using scoring models for systematically diminishing the complexities of subjective evaluations. Recent advances in the development of scoring models and their use in cost/effectivenes analysis have led to the investigation of their usefulness in the HIS priority setting process.

Information Costs in Hospitals

Interest was first drawn to the development of computer-based hospital information systems from both the observation of computer systems in other fields and the determination of the magnitude of information costs in hospitals. In a detailed industrial engineering study reported by Jydstrup and Cross (27), information handling in three Eastern hospitals was analyzed. The study results showed average information handling costs, for the hospitals studied, to range from 22.56 to 24.70 percent of total hospital costs. At about the same time, Lockheed Missile and Space Company, in an extensive hospital work analysis study (21), found that 30 percent of the total cost of hospital operations goes solely into manual processing of information. This magnitude of costs attributable to hospital information is further substantiated by a study of three Kaiser Foundation Hospitals, as reported by Richart (41), which determined information costs to range between 35 and 39 percent of total costs. These authors point out both the importance of the information function in the hospital and the potential for performance improvements and cost efficiencies through analysis and redesign of the information system.

HIS Definitions

A large majority of HIS related literature is devoted to the idea that this potential improvement can best be accomplished through the design and implementation of computer-based hospital information systems.

Although formal definitions of hospital and medical information systems are often only implied in the literature, the basic ingredients of an integrated, real-time, computer-based system are usually included. Collen in (7) describes a medical information system as a system "that utilizes electronic data processing and communications equipment to provide on-line processing with real-time responses for patient data within one of more general medical centers . . ." Collen further states that a hospital information system "is a subcomponent of MIS that handles the inpatient medical data." Schwarts (43) presents a more general definition which neglects the real-time requirement by stating: "An HIS system is defined as a high-speed computer-controlled, multi-station authorized access information flow network for the hospital. It has business office and patient care subsystems, and its function is to speed and simplify administrative and medical information handling." However, through his examples of the patient care subsystem, Schwarts also identifies the real-time characteristics proposed by Collen.

Benefits of Real-Time Systems

The potential benefits to be obtained from on-line, real-time systems have been identified by numerous sources. As related to Flagle's information evaluation criteria (12) of completeness, timeliness, reliability, operability, and cost, a strong case can be made for the superiority of real-time systems for the first three factors. The fourth, operability, is a measure of the human factors regarding the compatibility of the information system with the perception, the capabilities and the motivation of the people involved. Further experience and analysis are required before the ultimate effect of real-time hospital information systems on this factor can be properly assessed. Likewise, though initial development efforts of real-time systems have been exceedingly expensive, the eventual impact of such systems on operating costs is uncertain.

Siegel (44) goes further to say: "Because of the hospital's large volume of data, wide variety of information and full range of research interests, building towards a real-time, on-line system was the only practicable means to satisfy its numerous requirements." Schwarts (43) relates these intangible real-time benefits to a more practical level by forecasting HIS impacts in reducing patient stay, increasing bed occupancy, reducing transcription errors, providing data banks for research, and improving interdepartmental communications and overall management.

In spite of the considerable endorsement of potential real-time benefits, Ockenden and Bodenham (37) question not only the cost of real-time systems, but also the true need for real-time response capabilities in most hospital applications. Though they admit real-time systems would provide some advantages in the degree of improvement of information flow, their contention is that the additional cost, time and trouble of real-time systems over the requirements for a batch-mode system might not be justified by the incremental benefits to be received.

HIS Development Efforts

The first large-scale effort to design a real-time hospital information system was initiated at the Akron Children's Hospital in Akron, Ohio (4). Between 1961 and 1965 over 40 man-years of effort were invested in this single attempt to develop a total hospital information system using IBM equipment and support. The effort included a two year feasibility study which found that up to 40 percent of professional workers' time was spent in clerical or information-oriented activities. In (4), Cambell reveals that the initial grandiose plans for a comprehensive information system had to be abandoned in spite of the considerable resources involved. The narrowing of focus required at Akron, eliminating such areas as patient monitoring, laboratory test reporting, nursing notes, and research data banks from the computer-based system, was indicative of the unanticipated difficulties found in virtually every early HIS attempt.

The REACH system (48, 25) developed initially at Baptist Hospital, Beaumont, Texas, using Honeywell computers, is a real-time system with applications developed for patient records, bed census, drug files, employee records, and purchase order forms. Cathode Ray Tube (CRT) Terminals are used on the nursing units for visual display of patient records and other information. Like Akron, however, Baptist Hospital has experienced severe delays in systems development and equipment delivery. In addition, many members of the medical staff have resisted using the system, resulting in the duplication of effort in maintaining a partial manual system as well.

Downstate Medical Center's HIS as reported by Singer (46), Siegel (44), and Geisler (16), has been in operation since the hospital's opening in 1966. Its more than 100 CRT terminals are utilized with real-time responses in applications involving admissions, bed availability, bed census, patient billing, outpatient scheduling, pharmacy and the clinical laboratory. The real-time system is inoperative from midnight through 8:00 a. m. each day when various management reports are generated.

The National Multihospital Data Processing Service System (23), developed by the McDonnel Automation Company in Peoria, Illinois, has been partially implemented in three hospitals. The system is primarily administrative with operation applications in bed assignment, admitting, and accounting, although the continued development of other applications for pharmacy, central supply, and other areas is reported. The system uses on-line terminals on the nursing floors, but physician interaction is not required.

Other early efforts resulting in partial real-time HIS systems include projects at Massachusetts General Hospital, Boston Children's Hospital and the Texas Institute for Rehabilitation and Research, all described by Singer in (46). Medelco's THIS system (46, 29), now installed in numerous hospitals across the nation, is a much less comprehensive message-switching system designed primarily to eliminate intrahospital telephone communications and to allow for continuous availability of charge data. The Medelco system utilizes prepunched computer cards to identify the patient and describe the activity or service being requested.

Lockheed Missile and Space Company (15, 21) has developed and implemented portions of an HIS at El Camino Hospital in California. Although they have placed more emphasis in developing batch-mode business office services in recent years, design of a complete hospital information system has continued with the installation of a few real-time CRT terminals. The change in emphasis from real-time, patient-oriented systems to batch-mode business applications has also been seen in the HIS activities of IBM, GE and CDC. IBM's original purpose in developing a Medical Information System Program (MISP) (28, 46) was to provide a set of programs applicable to moderate size general hospitals at reasonable costs. However, the MISP development was subsequently re-aimed at less comprehensive applications in teaching and research hospitals while overall development and marketing resources were shifted to their Shared Hospital Accounting System, SHAS, and other IBM business systems. Similarly, the objectives of General Electric's MEDINET information system (46, 52) were changed from patient-oriented to administration-oriented and only the business office applications were developed fully. Although Control Data Corporation continues to plan for its real-time HIS package, MEDISCOPE (8), it too has stressed development of its automated accounting system, SHARP. Reasons for the shifts from real-time have usually been related to costs and software technology problems or to the current marketability advantage of the business systems.

Problems Encountered in HIS Development

A significant problem caused by the de-emphasis of patient-oriented systems was due to the misleading marketing claims which HIS vendors had prematurely made. Siler and Korn (45) indicate the problem by stating: "The computer field, unfortunately, seems to have difficulty distinguishing what actually has been done from what hopefully will be accomplished." Polissar (40) adds that "if one reads an article about an application and sees even one future tense verb, one can strongly suspect the system does not work yet and may be only a concept in some dreamer's head." Unfortunately, these false claims and the reaction expressed by Polissar not only have caused the failure of individual systems in meeting their objectives but also have held back many otherwise willing institutions from joining in developmental work. Hospitals unable to technically evaluate various systems and now distrustful of vendor assurances chose to follow a more cautious wait-and-see approach (45, 46).

From the writings of Polissar, Siler and Korn, Collen and others, the basic problems to be dealt with in developing real-time patient information systems can now be viewed more rationally. Vendor claims should be carefully analyzed before their full acceptance by health care institutions. The long term nature of real-time development, initially severely underestimated, should be fully appreciated and planned for. The extraordinary requirements for experienced staff in short supply should be aptly contended with. With the proper knowledge of the true magnitude of the task and of its inherent difficulties, HIS designers can now study more objectively the development of real-time systems.

General Characteristics of HIS Systems

From the overall history of HIS development presented in the literature, it is possible to extract the general characteristics of anticipated real-time information systems. One primary requirement is that the HIS must have a computerized multipurpose patient file (7, 16, 26, 36, 37), which receives and sends specific information for each HIS application. It must have interactive terminals (2, 21, 46) in which the user can inquire regarding patient data or obtain verification of an information entry with real-time response. The patient data system should be separate from but interacting with that of the business office and the design should allow for a modular approach to development and implementation (7, 17, 50). The need for modular development is inherent in the magnitude of the task and the limited availability of manpower and other resources. In (7), Collen points out that modular development requires well defined and well coordinated planning and discusses the importance of establishing objectives and realistic time tables for each phase. Collen and others give emphasis to the critical requirement that each module must be compatible with the rest of the system so that the central patient computer record can be realized. Van Brunt in (49), concurs with this emphasis stating: "a modular approach to the development of a large scale medical information system is mandatory, and careful planning, testing and evaluation are required at different stages of development."

Determination of HIS Priorities

While also selecting the modular approach to HIS implementation, Gillette, Rathbun, and Wolfe in (17) point out the priority setting problem which it creates, stating that both program priorities for the total hospital and the priorities of the computer systems development must be integrated in establishing the HIS master plan and implementation schedule. The need for HIS priority setting has been further discussed by Van Brunt (51) who states:

> The setting of priorities for the MIS applications is simultaneously a function of the needs of (a) persons or agencies who participate in the funding of any of the projects which are directly associated with the applications, and (b) the

> needs of the individual and services which are directly influenced by implementation of the applications.

In determining their own HIS priorities, Gillette et al., considered five factors: status of the current system, availability of a data base or data collection system, cost and time of development, analysis of benefits, and the sequence of development. The priority factors were then considered and combined subjectively and non-quantitatively in HIS planning meetings to establish the priorities of individual applications.

The Gillette factors can be logically divided into three groups of criteria: those involving incremental benefits, those relating to the technical sequence of development and those related to time and cost of development. The evaluation of alternative HIS applications using such criteria should be made by an interdisciplinary planning team representing all areas of the hospital to be affected. As Ockenden and Bodenham point out in (37), the evaluation of the applications' incremental benefits should be accomplished primarily by the specific users of each application, while the computer staff should determine the priorities from the sequence of development point of view, and the administration should be more involved in determining costs and resource requirements and relating them to the other criteria. Such wide and varied participation in the priority setting process would seem to stretch the limitations of unstructured subjective evaluation. The problem is further increased in the light of Freisen's (14) description of the traditional hospital organization as a complex of individual kingdoms, each fighting for increased individual power and increased prestige without concern for the improvement of the hospital as a whole. Although Freisen's description is admittedly exaggerated, the tendency for various hospital department chiefs to look out only for their own department has often been mentioned in the literature. In such an environment, it is difficult to conceive how one HIS priority plan could logically and equitably be obtained from group discussions and informal aggregations of individual HIS assessments.

Determining Incremental Costs

Inherent in establishing priorities within a modularly implemented system is the need for determining the appropriate costs and other resources required for each potential application. Because the nature of an integrated system requires the development of overhead programs such as the central patient file or terminal user identification software, the question arises of how to distribute these overhead costs to each of the proposed applications. Unfortunately, the HIS literature is completely void on this issue and has only minimal mention of cost estimates of overall systems (18, 22, 43).

Solution Approaches to Other Priority Problems in the Health Field

Although the problem of HIS priority setting seems unique because of its extraordinary requirements for evaluating benefits involving quality of care, as well as consideration of the technical sequence of development and the incremental cost of implementation modules, it is not unlike other priority problems encountered within the health field. The basic problem is characterized by the need to have various subjective criteria evaluated by numerous and divergent members of the health community and combined with cost measures and other objective determinants to obtain a ranking of projects for implementation as bugetary and other resource limitations permit.

One variation of this problem, often encountered in federal health care programs, involves funding one or more of a list of potential projects subject to a limited budget. The effects of each program on the health of a target population are often uncertain and cannot be meaningfully expressed in monetary terms or any other absolute quantification. Subjective assessments of relative benefits of these projects must be combined with project costs in a way similar to that needed for the HIS priority problem. In facing the project funding problem, the Indian Health Service (IHS), an agency of the U. S. Public Health Service, has developed a priority setting methodology (24) utilizing a matrix factor analysis technique similar to that proposed by Muther (34) for alternative evaluation in layout planning. The IHS methodology involves determining the objectives for each project; rating the importance of each objective against a set of established criteria; comparing the probable percent accomplishment of each project objective by alternative plans for the project; obtaining project alternative effectiveness rating by multiplying the objective importance ratings by the probabilities of accomplishment; and determining project priorities by dividing project cost by effectiveness and ranking in increasing order. The methodology can accommodate the inputs of numerous individuals in each of the evaluation steps and results in documentation of the reasons for project selection.

A similar use of the matrix factor analysis or scoring model technique was incorporated into an extensive study to determine how best to allocate limited renovation funds among various departments in a large federal hospital (39). First, the departments eligible for renovation were identified and alternative modernization plans were developed for each. Next, each alternative plan was rated, using a scoring model technique, according to the relative improvement it offered to the operation and function of the department, without direct consideration of the hospital whole. The third step was to establish how critical the renovation of one department was relative to all others. Again the scoring model was used with individuals from numerous disciplines participating in the evaluation. The criticality ratings were then correlated with the improvement ratings by multiplication and divided into investment cost to obtain a cost/effectiveness index which was used to rank the departments and alternatives.

In both of the cited priority problems, numerous individuals from various disciplines were involved in making complex subjective judgements regarding the benefits of proposed alternative projects. In each, the problem complexity was systematically diminished through the use of a scoring model technique. The similarities between these priority problems and those of HIS development have led to the investigation of scoring models in the reported research.

Development and Validation of Scoring Models

Although the structures of most scoring models discussed in the literature appear to be ill-defined and arbitrary in nature [(10, 33) for example], recent research by Moor and Baker (31, 32) points out the sensitivity of model results to changes in various attributes of the model design. Specifically, the influence of changes in the number and width of scoring intervals, the method of combining the various criteria, and the choice of performance distributions for each criteria, on the correlation of the model's results with those of a benchmark model are shown to be quite significant. In (31) Moore and Baker generalize their findings to suggest acceptable ranges or choices for model attributes and a verification method based on correlation with other financial evaluation models.

This establishment of guidelines for scoring model development should do much for reducing the arbitrary nature of scoring model design in all areas of application; however, the proposed method of validation appears to be infeasible for models dominated by subjective criteria and not having suitable, more quantitative substitutes with which to compare. Instead, a validation based upon the model's yield of an acceptable consensus among the participating decision makers would seem to provide the best measure of model appropriateness. Further discussion of the literature regarding scoring model design is presented in Chapter IV.

Cost/Effectiveness Ratios in Priority Rankings

In the two scoring models described for priority setting in the health field environment (24, 39), a cost/effectiveness ratio was obtained and used to rank project priorities. Charles Hitch in (20) has described such ratios as "particularly treacherous as operations criteria." Fox (13) and Novick (36) further discuss the disadvantages of ratios and point out that they should be used only when either the benefits or costs of all projects are equal, since wide differences in the scale or magnitude of various alternatives might make comparisons meaningless. It should be noted, however, that the decisions for which Hitch, Fox, and Novick are considering ratio criteria are primarily concerned with evaluating the relative worth of mutually exclusive projects and differ from the priority problem. The basic HIS priority problem is to arrange the candidate alternatives in an order for sequential implementation such that the applications with the greatest return in benefits per development funds expended would be selected first. The problem assumes that all candidate applications are independent and that all will be eventually undertaken. For these reasons, the implications of scale and magnitude differences among alternatives are not present in the pure priority problem and the use of cost/effectiveness ranking seems appropriate. Unfortunately, the preceding argument in favor of ratio criteria breaks down when sets of mutually exclusive alternatives for various subsystems are introduced into the priority problem. In such cases, the use of incremental cost/effectiveness analysis, to make selections among mutually exclusive applications before the establishment of application priorities, appears warranted.

Concluding Remarks

The following conclusions can be drawn from the literature survey presented herein:

1. The importance of hospital information systems has been well recognized.
2. The trend in HIS development is toward real-time integrated

systems with a modular approach to implementation.

3. Although a need for priority determination among HIS applications has been identified for both the potential users and the funding sources of hospital information systems, no systematic methodology for such a purpose has been developed.
4. Certain scoring model evaluation techniques used for priority setting in other health field areas seem applicable for use in setting HIS application priorities.
5. Comparative validation of the scoring model with other more quantitative benchmark models is not feasible when subjective qualitative criteria are dominant. Validation by user evaluation appears to be the best measure of model appropriateness in such cases.
6. Cost/effectiveness ratios seem appropriate for the basic priority problem; however, special care regarding sets of mutually exclusive alternatives must be made to avoid the magnitude and scale difference difficulties inherent in ratio criteria.

CHAPTER III

OBJECTIVES, PROBLEM ENVIRONMENT AND GENERAL APPROACH

Purpose and Selected Approach

The general purpose of this study is to develop a methodology for determining implementation priorities among candidate applications to a real-time, patient-oriented hospital information system. The need for such a methodology as a part of the overall HIS planning process is clearly evident from the increasing trend toward modular HIS development as reported in the literature.

Since the task of establishing priorities is one of evaluation and analysis, the developed methodology is centered upon an evaluation tool, the scoring model. A scoring model is a mathematical model which integrates the use of several selected criteria in obtaining an overall evaluation score for each alternative action considered. Since the scoring model produces a single evaluation value, it can be combined with investment cost determinations to allow cost/effectiveness analysis of the alternatives.

Several attributes of the scoring model method make it particularly attractive to the HIS priority problem. First, it allows a highly complex evaluation problem to be systematically broken down into simpler elemental considerations. In addition, the technique allows the direct participation of a number of evaluators and, therefore, can serve as an aid in obtaining a consensus implementation schedule from an HIS planning team made up of representatives from diverse disciplines and functional areas of the hospital. Scoring models are also well suited for considering the many highly subjective criteria particularly common to the health field. Finally, the use of a scoring model provides substantial documentation of the evaluation process and facilitates re-evaluation and review if the candidate alternatives or the decision conditions change. Because of these desirable characteristics and also since scoring models have been utilized with some success in other areas of health care planning activities, the technique was chosen for inclusion in the methodology.

Objectives

The following specific objectives were established as the primary elements in pursuing the general purpose of the study:

1. The development of a general planning approach to setting HIS priorities.
2. The establishment of guidelines and procedures for the development of scoring models to evaluate the improvement in effectiveness offered by candidate HIS applications.
3. The development and use of a scoring model to establish HIS priorities for a mock hospital as a demonstration of the general methodology.
4. An evaluation of the applicability of the methodology to HIS priority determination.
5. The identification of promising and important areas of the HIS priority planning process which are appropriate

for additional research.

Scope and Limitations

The developed methodology is aimed at the establishment of priorities among candidate applications to a real-time, patient-oriented hospital information system. It provides procedures for selecting among mutually exclusive applications and for ordering the selected applications within an implementation schedule. No procedures are included for the cost justification of either the overall real-time system or any of its applications, as such procedures are beyond the scope of this study. In addition, no specific scoring model is offered for universal use in HIS priority determination; rather, the procedures and considerations required for each institution to develop its own customized scoring model are described within the general methodology and are demonstrated by the scoring model development for the mock hospital. The use of the methodology by a specific institution would therefore necessitate retracing the model design activities demonstrated by the trial application. Since one of the main values of the methodology comes from the participation of the HIS planners in the actual model design, a more standardized methodology would probably be self-defeating.

In addition, because of the highly subjective nature of the factors considered in the scoring model, direct validation of the model and methodology is not pursued in this research. Instead, however, the use of the approach is demonstrated on a mock hospital and is subjectively evaluated by members of the HIS planning committee at the Medical College of Georgia. The purpose of this evaluation is to provide insights into the methodology's general applicability to real-world HIS planning.

Problem Environment and Assumptions

The priority setting process cannot be studied without reference to the overall HIS planning and decision environment. As indicated in the discussion above, the developed methodology is useful only after the commitment or cost justification of the overall HIS has been established. Further, it is assumed that such a commitment has determined the basic configuration of the overhead computer systems, which would include the central processor, basic auxilliary and support equipment, and a minimum number of multipurpose remote terminals in the nursing units and other selected areas of the hospital. For the purposes of this discussion, specific software or equipment is considered a part of the overhead system if its use is needed by all or most of the subsystem applications under consideration. The overhead software, development, and start-up costs, as well as the costs of any unused capacity in the overhead system are treated as fixed and only the incremental development costs are apportioned to each application subsystem. The consideration of such overhead as fixed is necessary if the methodology's assumption of application independence is to be acceptable. Even with the use of fixed overhead costs as proposed in the methodology, the assumption of cost independence among applications appears weak and should be given further consideration as discussed in Chapter VI.

Because of the assumed fixed nature of the overhead system, the modular development of HIS activities must be considered on the basis of phases of discrete jumps in overhead investment with continuous development and implementation of specific applications within each phase. In that way the basic overhead system would not change during a particular planning horizon of from one to three years. The developed scoring model would first be used for ordering the implementation priorities of those applications deemed feasible under the initial overhead system. If later, new applications are identified, the scoring model would be reapplied and the results would be used to update the implementation schedule. Such an update would also occur at the end of each planning horizon and at the time of any increase in the overhead system. Of course, the expansion of the overhead system would allow applications which were previously infeasible due to technical incompatibilities, to compete with the original candidate applications for priority positions in the implementation schedule. For simplicity, the implementation process is assumed to be purely sequential in the initial determination of the schedule, with no two applications being developed simultaneously. This restriction would be removed in adapting the model results to an actual implementation plan. An example of an HIS development schedule which illustrates the above described planning and development structure is presented in Figure 1.

Another factor in the HIS planning environment involves the designation of the actual decision making authority and the individual participants in the priority setting process. The general methodology assumes that an HIS planning committee made up of representatives of the medical staff, computer center, administration, and other key areas of the hospital has been given the responsibility to recommend an HIS implementation plan. The recommended plan would then be presented to the hospital administrator and governing board for final

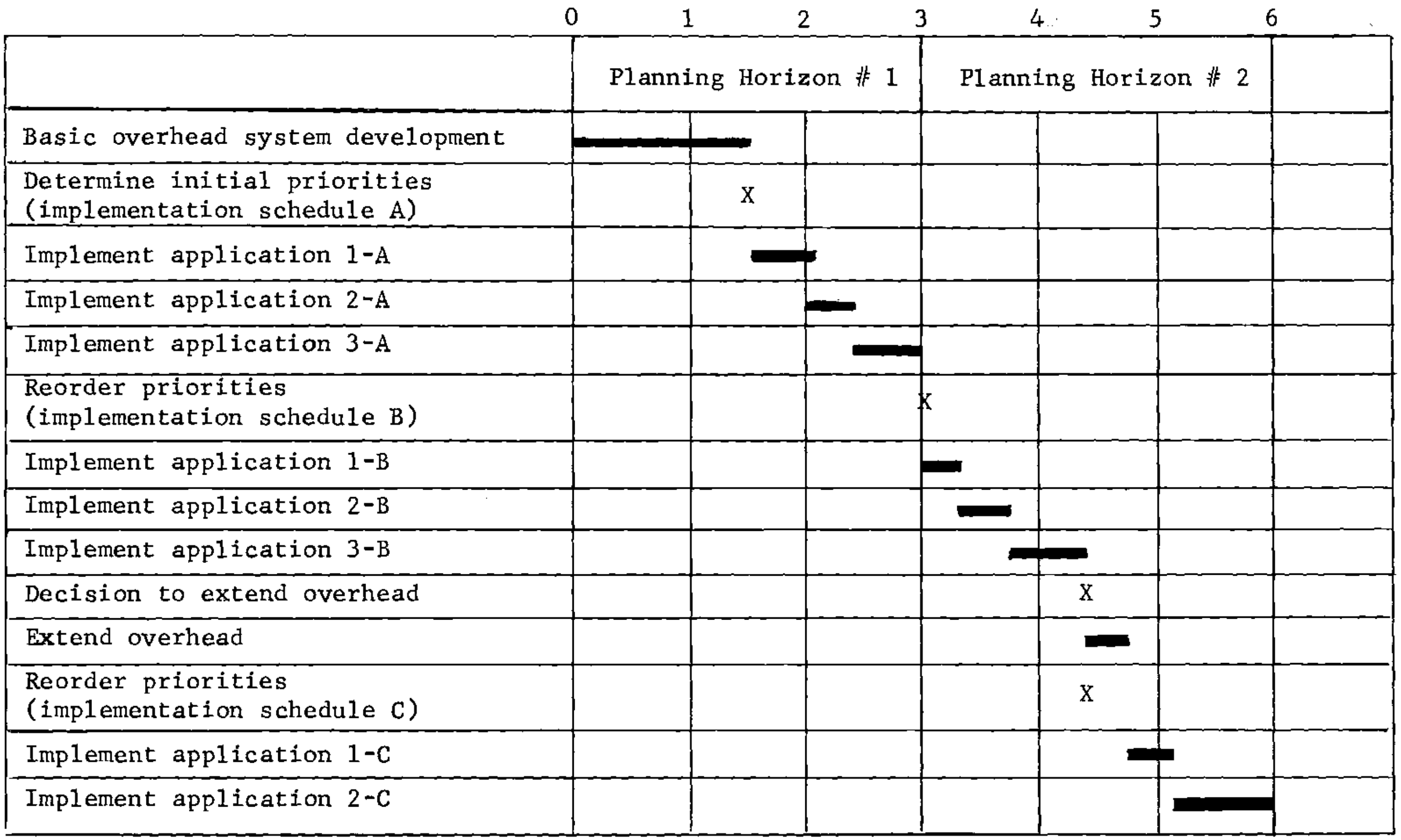

Figure 1. Example HIS Development Schedule.

approval. The committee would use the methodology to structure their evaluation of the candidate applications and to obtain an initial priority ranking according to their cost/effectiveness ratios. Although these rankings suggest a tentative HIS implementation schedule, in most cases the planning committee will need to use this schedule along with an extensive sensitivity analysis of the scoring model results as inputs to the development of the actual implementation schedule. Other inputs would include additional considerations regarding the possible parallel development of certain applications, the interdependencies among applications, and other complexities not treated in the scoring model.

From the above discussion, it is seen that cost/effectiveness analysis using the scoring model technique will not necessarily create the optimum implementation schedule itself, but rather, it is intended to sharpen the intuition and judgement of the planning committee members so that they might make better evaluations and priority decisions. This is accomplished through the committee's participation in the systematic design of the scoring model and the analysis of its results. In addition, this approach should aid the committee in gaining a consensus from its initially diverse participants, and therefore increase the support for and acceptance of the recommended schedule of priorities.

Demonstration of Methodology

Because the developed methodology consists primarily of general guidelines for scoring model development and priority setting procedures, it is evident that a demonstration of these guidelines and procedures as applied to a specific HIS priority problem is necessary for an acceptable examination and explanation of the proposed methods.

Although many hospitals across the nation are currently studying the possibility of real-time information systems, none were available who had reached the point where priority determination among applications was required. In spite of the premature need for priority planning in their own HIS evaluation activities, members of the HIS planning committee from the Medical College of Georgia and the Eugene Talmadge Memorial Hospital agreed to assist with the methodology's demonstration. The planning committee consisted of an obstetrician representing the medical staff, a hospital administrator, a computer systems analyst, two health systems engineers, and the director of the College's division of hospital research and development.

It was decided that a mock hospital with fully described workloads, patient mix characteristics, and information system performance levels could be used for the demonstration, with the Medical College planning team taking the role of the HIS planning committee for the mock hospital. The hospital was designated as a non-teaching facility to reduce considerations of education and research objectives and hence simplify the demonstration. Because of the considerable effort required to develop fully detailed descriptions of candidate HIS applications, only four were used in the evaluation. It is felt that four applications are sufficient to demonstrate the methodology's procedures.

The planning committee, working with the author, developed and evaluated a scoring model for the mock hospital. The participants then provided their appraisals of the usefulness and applicability of the approach itself. A more detailed description and discussion of the trial application and demonstration of the methodology is presented in Chapter V, while the general methodology itself and the guidelines for specific scoring model development are included in Chapter IV.

CHAPTER IV

A METHODOLOGY FOR DETERMINING HIS PRIORITIES

The methodology developed for setting priorities among candidate HIS applications, using the general approach described in Chapter III, includes several steps. First, the information subsystems of concern must be analyzed to determine the information requirements and needs for improvement. Next, candidate HIS applications must be identified, described, and analyzed through a series of data gathering and screening procedures. A scoring model must then be developed to allow systematic consideration of all relevant factors in determining the relative improvement in effectiveness offered to the hospital by each candidate application. Once determined, the overall measure of effectiveness for each alternative should be related to development cost to allow the selection and priority ranking of all applications. To provide an overview of the priority setting methodology, a flow diagram of its various steps is presented in Figure 2.

Primary emphasis in this research was placed on the scoring model development portion of the methodology. The other steps were studied and are presented only to suggest a general approach in which the scoring model might best be applied. These supplimentary portions of the methodology were developed primarily from general study of the literature and analysis of the overall planning environment, and are presented without specific supporting documentation. Accordingly, the primary purpose of this chapter is to present a comprehensive discussion

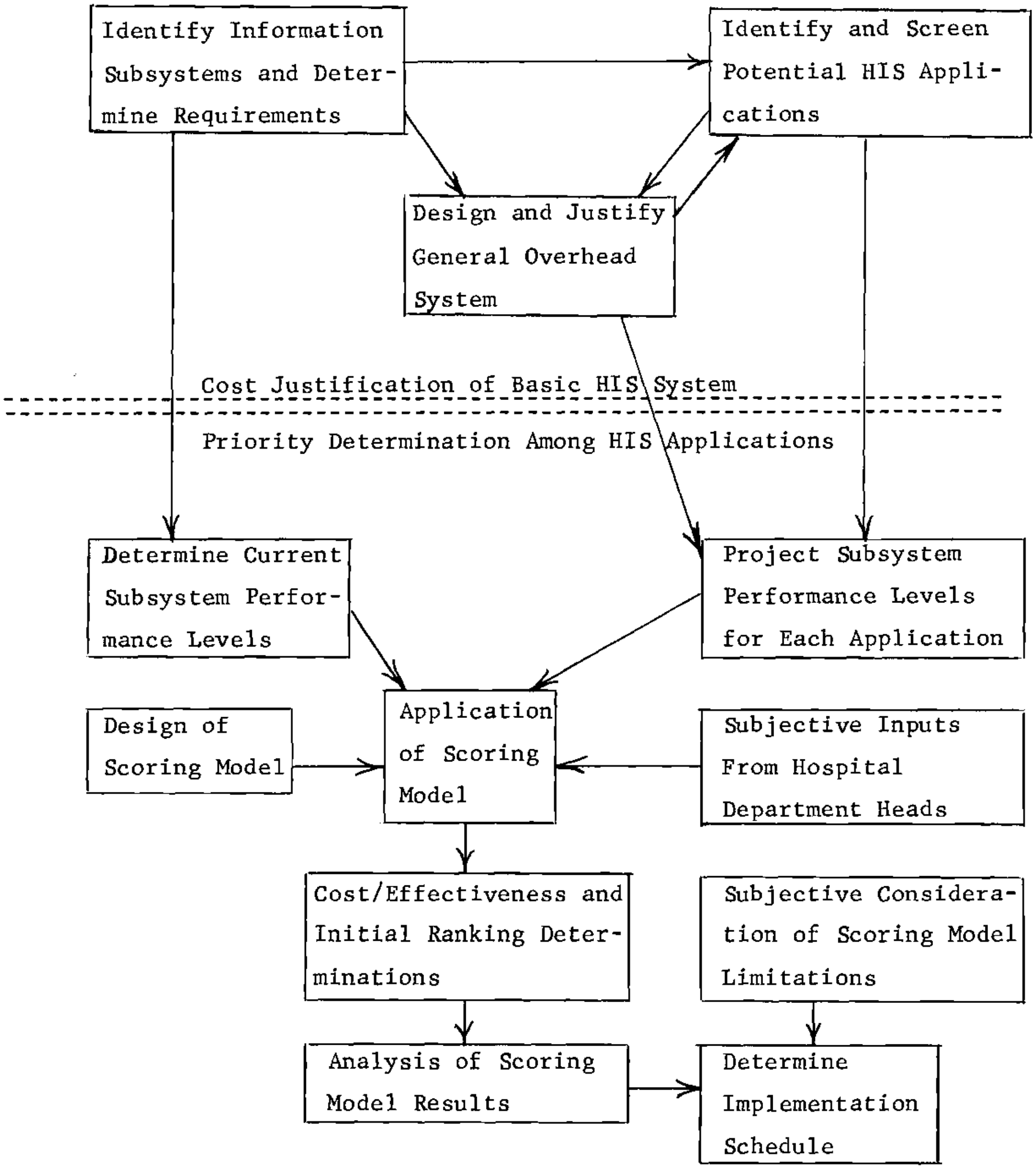

Figure 2. Flow Diagram of Priority Determination Methodology.

of the considerations and procedures involved in designing a scoring model for HIS applications and to relate the use of such a scoring model to the other aspects of the suggested methodology for setting HIS priorities.

Analysis of Information Subsystems

Perhaps the most critical phase in designing a patient oriented information system is that of determining and quantifying the information performance levels desired of each subsystem and assessing the need for attaining them. Although interrelated within the overall HIS, the individual information functions of the hospital are sufficiently separable so that they may be analyzed as individual HIS subsystems. At an early stage in HIS planning, these subsystems should be exhaustively identified and defined. A listing of such information subsystems might include laboratory, pharmacy, radiology, medical records, patient billing, admitting, management systems, and dietary as well as other information functions of the hospital.

Each information subsystem should then be analyzed to determine quantified information requirements in the form of the content and frequency distributions of each type of information transaction. Such information might be found through work activity studies employing statistical sampling techniques (1). The results of the transaction volume determinations should then be extrapolated to obtain quantified estimates of information requirements for the future.

In addition to transaction volumes, the quality aspects of the information subsystem must be defined and measured (12, 37). These aspects can best be measured in relation to the performance levels of various information attributes such as timeliness, accuracy, and reliability. Quantitative measures of response times, cycle times, error rates, and reliability should be obtained through direct observation of the subsystem in operation. While the subsystem is being scrutinized to determine information requirements and present performance levels, efforts should be made to estimate both the current costs of the subsystem and the potential cost savings due to improvements in the manual system. The cost estimates for the improved manual system would then be compared with those for each automated alternative to determine displacement cost savings.

Identify, Describe, and Screen Potential HIS Applications

The determination of the information requirements and performance level measures for each information subsystem should provide a sound basis for the development and analysis of candidate HIS applications. Alternative applications suggested in the literature, previously implemented at other facilities, or designed by the in-house staff, should be admitted to a preliminary screening and modification process. Site visits to view operational HIS applications and to discuss current development ideas and problems at other health care facilities appear helpful in overcoming both the time lag and lack of depth of discussions in the literature. All identified applications should be catalogued according to the information subsystems they involve and described briefly before being placed into the screening process. In general, the screening should eliminate from further consideration those applications possessing unacceptable characteristics such as legal and professional code violations, and limit the number of alternatives which undergo detailed analysis and development. However, rather than completely discarding applications lacking in certain requirements, the screening and review process should determine how each could be modified to best fit the information needs. This modification is, in effect, a design procedure in which new applications are synthesized from the stronger aspects of unacceptable ones.

Because of the costly and time consuming task of obtaining detailed performance and cost estimates for applications, several screening iterations appear to be desirable, with the depth of analysis increasing in each succeeding review. In general, the cost of additional information at each screening stage should be weighed against the possible elimination of good proposals because of inadequate data. In the final stages of analysis, the description of each application should relate to the specific criteria to be used in the evaluation model. Quantitative performance level estimates for each application should then be determined and described in a way which facilitates comparison with previously determined current levels of performance. In addition, for those criteria not measurable by specific performance levels, the qualitative inputs and findings should be summarized to provide a sufficient information base from which the scoring can later be made.

For all applications entering the final evaluation and scoring process detailed information must be obtained, describing the precise procedures that the application will require, estimating the volume capacity and response times for each type of transaction and projecting both development and operating costs for the application's implementation. This analysis process is a painstaking and time consuming one, but is essential to the rational evaluation of the alternatives. In addition to or in conjunction with the planning committee's analysis of each application, assessments of the candidate applications should be made by representatives of the prospective users of the new systems and presented to the evaluation team. For example, the head of the radiology department would describe to the committee the expected impact that each candidate radiology-related application would have on each aspect of information system performance. The user inputs may well provide the most valid evaluations of each application's potential performance and should be carefully considered by the planning team for incorporation in the actual application evaluation.

Development of Scoring Model

Because of the vast quantity of complex evaluation inputs from both their own analysis and the users' presentations, the planning committee's task of integrating it all in a meaningful evaluation of each application is extremely difficult. The large number of significant factors which must be considered in this evaluation requires some formal structure which would allow separate consideration of each individual factor while combining all factors in a manner consistent with their logical interrelationships. The proper development and use of a scoring model provides such a structure, systematically breaking down the complexities of the evaluation into separate analyses of individual criteria.

However, confidence in the use of scoring models in decision making has been severely limited by the seemingly arbitrary manner in which models have been constructed. Recent research (19, 31, 32) has now begun to point out the consequences of model structure and to provide guidelines for developing scoring models which are more consistent with the intrinsic relationships among the decision determinants. Not only the choice, independence, and combination of criteria, but also the form and range of the scoring functions, the estimation of the distribution of each criterion's scores, and the method of model application have been found to significantly alter model results. The guidelines and procedures for including such considerations directly in the scoring model design are discussed in the following sections.

The specific purpose of such a scoring model is to obtain a one value measure of the change in the effectiveness of the hospital which would be expected from the implementation of each candidate application. Because the measure would represent the benefits of the improvements over a period of time, it is expressed in "effectiveness units" per year. Although these units are not themselves in terms of dollars, they can be related to development or investment costs by obtaining a cost/effectiveness ratio for each evaluated application. These ratios are expressed as dollars per "effectiveness unit" per year. Since the priority setting objective is to maximize the effectiveness improvement per investment dollar, a ranking of independent applications according to their increasing cost/effectiveness ratios would result in an optimum implementation schedule. This is based upon the assumptions of sequential development, a constant ratio of development costs to development time, and no preference for current benefits over future benefits. The optimality of implementation according to rank ordering under these assumptions can be demonstrated by an example such as that described on page 61. Discussion regarding the optimization by rank ordering and the inconsistencies which appear if these assumptions are eliminated is presented later in this chapter.

Selection of Criteria

The proper selection of criteria forms the foundation for a sound scoring model. Because of the uniqueness of each health care institution, particular care must be taken to customize the formulation and selection of criteria to the specific institution and decision making environment in which the model will be applied. For this reason it is essential that the full HIS planning team actively participate in the criteria selection and model building process.

Miller (30) correlates the selection of criteria to the listing of all significant performance objectives. Although this relation is more visible in the assessment of proposals aimed at performing the same task and function, it is also useful to consider criteria relevant to the priority setting process in the light of general information system objectives and even the overall objectives of the hospital. Smalley (47) discusses hospital objectives as interrelated goals involving patient care, education, and research with the importances and relationships between the three highly dependent upon the specific organization and uniqueness of each hospital. Unfortunately, these objectives are usually too ill-defined and inspecific for direct use in the model.

More measurable and definable attributes are associated with the objectives of information systems. Peformance of these functions normally can be measured by the analysis of content, accuracy, reliability and timeliness of information outputs. Although these attributes are somewhat quantifiable, their impact on the overall objectives of the hospital is more difficult to define and necessitates subjective evaluation of each criterion.

Other common hospital goals which relate to the primary objectives of the hospital and are affected by the hospital information system include the attainment of cost efficiency, a favorable image with the public, patients, and staff, and sound management policies and administration. It is the task of the HIS planning committee to consider carefully all such objectives and to formulate criteria to best represent them in the evaluation process. The criteria selected by the medical college planning team for the trial application are presented in Chapter V.

Although criteria selection should remain flexible enough to allow the consideration of all important factors, care must be taken to eliminate insignificant considerations which impede and complicate the model's use while contributing little to its validity. The planning committee should strive for criterion independence in their selections. However, in listing candidate criteria, particularly with inputs from a multi-member HIS planning group, sets of basically different criteria having substantial overlaps regarding certain factors often occur. Because such overlapping results in over weighting the importance of a particular factor, attempts should be made to minimize overlaps. Although this duplication of coverage is sometimes the result of semantic differences and hence rectifiable by elimination of one of the criteria; in other instances of overlap, the omission of either criteria would cause a substantial loss of information and model validity. In such cases combination of the two or more criteria either by verbal description or by separate grouping within a criterion hierarchy seems most applicable.

Another critical attribute of model criteria is measurability. For valid assessment of criterion satisfaction, a method and scale for measuring performance levels with respect to the criterion must be constructed. Criteria directly representing quantifiable performance present no problem since their measures of performance can be directly related to the scoring scale. However, because of the dominance of qualitative criteria in the HIS evaluation problem, direct subjective assessment of criterion satisfaction must be used. Further considerations of criterion measures are included in the discussion of scoring functions later in this chapter (p. 38).

Model Structure

Because an HIS evaluation model must be able to represent complex relationships among many determinant factors of the decision making process, the development of the scoring model's structure must allow for flexibility in grouping and combining all criteria. Moore and Baker (32) have demonstrated one aspect of the model structure's impact on scoring model results by comparing the outputs from multiplicative and additive models using identical criteria. The comparison indicated that the two methods of criterion combination lead to substantially different results. Miller (30) presents the use of a hierarchial structure in which the overall performance objectives are broken down into groups of criteria representing the lower level objectives. However, Miller describes only additive relationships both within and between each criterion grouping. In contrast to strictly additive or multiplicative combination, intuitive analysis suggests that both methods may often be appropriate within a single scoring model and that the planning committee's interpretation of the logical relationships between specific criteria should determine their structural position and method of combination in the model. For example, it would seem that the total value to the hospital of direct improvements in an information subsystem is best represented by the multiplicative combination of a criterion measuring the need for improvement and one measuring the degree of improvement anticipated. The degree of improvement, however, appears to be an additive function of several criteria measuring various performance attributes of the information system. Such a mixed model can be easily accommodated by the Miller criterion hierarchy by the addition of node symbols to denote the mode of combination as shown in Figure 3. In this example criterion hierarchy many criteria deemed important have been omitted for the sake of simplicity. A more realistic scoring model which was used in the methodology demonstration is presented in Chapter V. However, these criterion hierarchies should be used only as examples to show HIS planning groups how their own selected criteria might be related and combined within the environment of their own specific institutions.

Although the availability of a mixed mode model may allow greater flexibility in representing the proper decision process, it introduces several complexities and constraints on the mathematics of the scoring

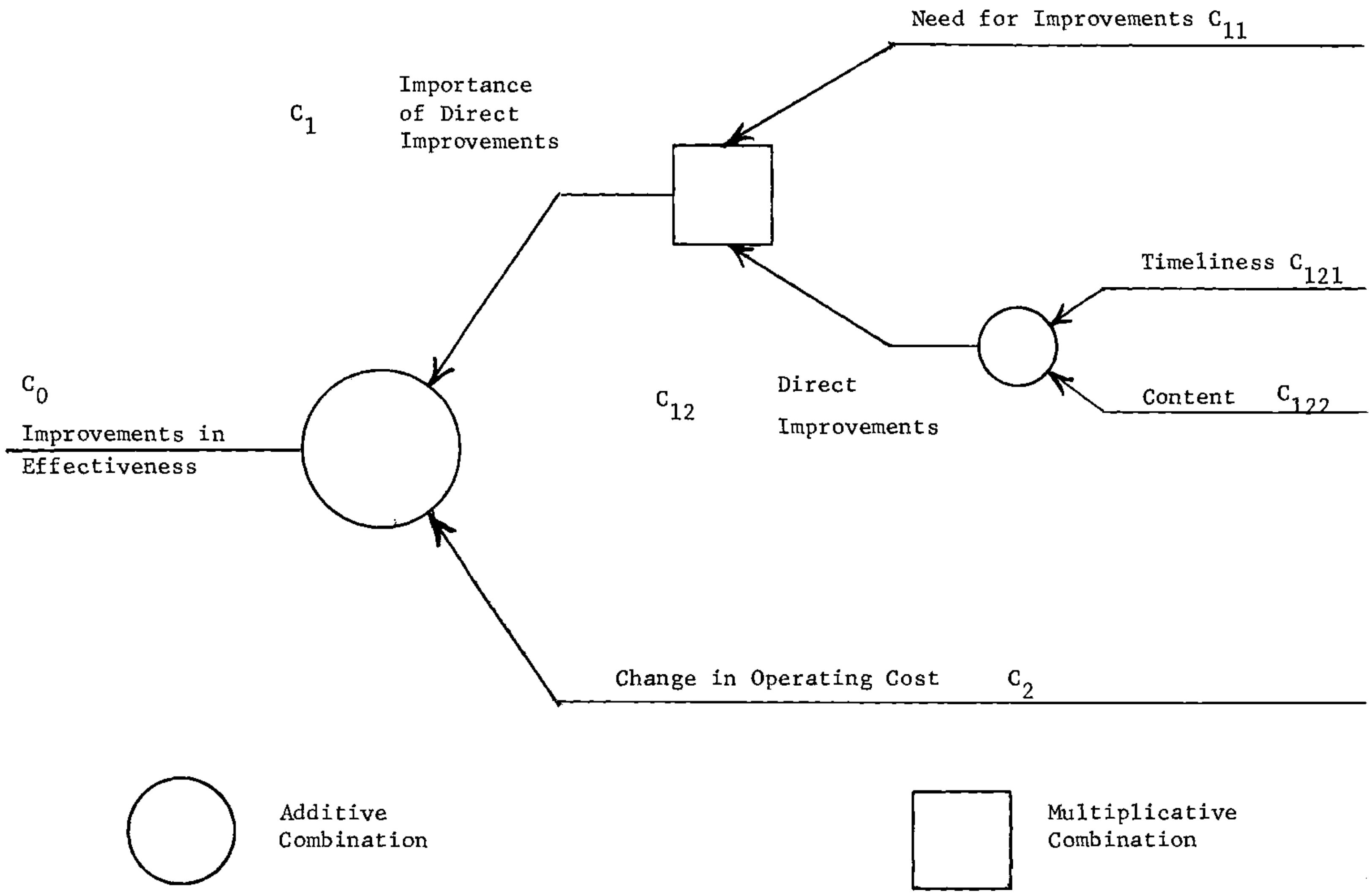

Figure 3. Example Criterion Hierarchy.

model and the formulation of weightings and scoring functions for each criterion. Discussion of such considerations are included in the following sections of this chapter.

Criteria Weighting

Once the criterion hierarchy and model structure are defined, a method for weighting the relative importance of the criteria in each subset or hierarchy level must be established. For groups of additive criteria, numerous methods have been suggested for this task. In general, all methods result in a constant coefficient being assigned to each criterion as an importance multiplier of the criterion score. Eckenrode (11) described and compared six such methods of weighting, concluding that there were no significant differences in the derived sets of weights. The methods studied were ranking, rating, partial paired comparisons (two methods), complete paired comparisons and successive comparisons. Because these methods have been sufficiently described by Eckenrode and other (3, 11), their descriptions are not repeated here.

All of the weighting methods mentioned above establish importance coefficients for all additive criteria as a part of the model structure. Once these coefficients are determined, they remain constant for all applications considered in the evaluation.

As mentioned in the previous section, the introduction of the multiplicative combination of criteria complicates the weighting process. To place unequal weights upon two such criteria, it appears necessary to utilize some form of exponential weighting. For example, if criterion A were deemed more important than its multiplicative counterpart B in determining a measure of the overall objective C, a calculation scheme where $C = A^x \cdot B$ seems appropriate (where $x > 1$). Such a weighting scheme should be considered by the planning team only if the intrinsic relationships between the criteria strongly suggest it, since exponential adjustments would significantly increase the complexity of the scoring model mathematics.

Although many valid weighting methods have been developed, none are independent from the other aspects of the model and great care is required in developing scoring functions and adjusting the results of criterion combinations if the integrity of the assigned weightings is to be maintained.

Criterion Definition and Scoring Functions

Because each criterion is to be used by many individuals to evaluate many different proposals or HIS applications, extreme care must be taken in defining each measure and in creating scoring functions which promote consistency both among evaluators and between the various criterion groupings in the model. As defined by Miller (30, p. 38), a scoring function is "a mathematical rule that assigns a unique worth score in points to every possible value of some physical performance measure." He further states:

> Most scoring functions will take the form of mathematical formulas and/or graphically depicted mathematical curves. However, . . . some will take the form of direct worth assignments without the aid of either formulas or graphs. In this case, scoring functions are thought of as implicit in the mind of the decision maker.

Because of the dominance of subjective criteria in health field planning, the direct worth assignments of criteria seem most applicable.

Direct worth assessment scoring functions may be either continuous or discrete. For discrete scoring functions, the evaluator must select from several scoring intervals the one which best represents the worth of a particular candidate application in regards to the specific performance measure or criterion involved. A point value previously determined to be appropriate for the interval is then assigned as the evaluation score for the application. Each scoring interval is normally defined by either numerical or narrative descriptors to guide the evaluators in relating their worth assessments to the evaluation scores. These descriptors are helpful in allowing more consistent scoring among the evaluators. Recent research by Moore and Baker (31) suggests the importance of maintaining intervals of equal width and of selecting the appropriate number of intervals for each scoring function. Although the discriminatory power of the Moore-Baker model appears to increase with an increasing number of scoring intervals, a maximum number of nine such intervals was cited for use when judgmental data are involved. For the highly subjective criteria encountered in HIS planning, it would appear difficult to adequately define even a much smaller number of intervals with descriptors connoting equally spaced worth assessments and assuring similar interpretations by each evaluator. The resulting limitation on the number of appropriate scoring intervals for subjective criteria would reduce the discriminatory power of the scoring model significantly.

An alternative to the interval type of scoring function involves the use of a continuous scoring scale. Here, the evaluator has maximum flexibility in assigning each HIS application a value from the scoring scale. However, if no descriptors are provided, each evaluator must relate his own worth scores to the scale in a highly arbitrary manner, resulting in significant scoring inconsistencies even where the actual worth assessments are compatible. These inconsistencies can be alleviated to a degree by adding descriptors to guide worth assignments on the continuous scale. Again, however, these descriptors must connote appropriate and consistent worth measures to all evaluators.

A compromise approach appears to be most feasible. It is therefore suggested that scoring functions developed for highly judgmental criteria be primarily of the continuous scale type with descriptors included at the endpoints to identify the worth range and additional descriptors assigned wherever their connotations can be made appropriate to a specific point on the scale. Such a descriptor placed in the vicinity of the midpoint of the scale would be a particularly helpful guide to the evaluators.

Other results of the Moore and Baker research indicated the apparent importance of relating the range of the scoring function of the range and probability distribution of the criterion performance levels appropriate for the population of HIS applications being evaluated. In effect, by mismatching the two ranges, the model builder inadvertently places a higher or lower weight on the criterion and biases the model results. For the same reasons, it appears desirable for the scoring ranges for all criteria be identical.

Though errors in the estimation of the performance distributions' true means were shown to have a significant effect on Moore and Baker's scoring model results, errors in the estimates of dispersion and distribution functions caused relatively little impact. From this finding it would tentatively appear that approximations of actual performance distributions by simpler distributions, such as standardized, normal distributions, would introduce little bias into the results. Such approximations would be of significant help in reducing the complexities of the scoring model calculations as discussed in the following section.

Because it is unlikely that a large enough number of previously evaluated HIS applications would be available for analysis in determining performance level distributions, subjective probability distributions for each criterion will usually have to be constructed by discussion and questioning within the planning team and among other members of the hospital staff. Fortunately, the apparent insensitivity of scoring model results to minor distribution changes greatly reduces the necessities for detailed determination of performance distributions and allows normality approximations. Examples of scoring functions and estimated performance distributions used in the trial application are presented in Appendix C.

Scoring Model Mathematics

In developing the scoring model mathematics, care must be taken to avoid compromising the consistency of either the criterion weightings or the scoring ranges. To illustrate the development of appropriate scoring model calculations, the mathematics are presented here for the example scoring model discussed earlier and illustrated by the criterion hierarchy shown in Figure 3.

For this simplified scoring model, it has been determined by a hypothetical HIS planning team that the total improvement in effectiveness is an additive function of the degree of operating cost changes and the importance of direct functional improvements due to implementation of the HIS applications. Figure 3 further indicates that the measure of the importance of direct improvements is best obtained through the multiplicative combination of one criterion measuring need for improvement and a separate measure of the actual degree of improvement itself. Finally, it is shown that the two criteria measuring timeliness and content were considered to be the only major factors affecting the measure of direct improvement. Hence, the hierarchy tree succinctly illustrates the relationships between all criteria to be considered in the evaluation.

Now, let it be assumed that the estimated distribution of performance scores for each criterion is normal having a mean of $\mu = 0.5$ and a standard deviation of $\sigma = 0.1938$. With such a distribution, the probability is 0.99 that any random score will fall between 0.0 and 1.0. Since any normal distribution can be adjusted or standardized to fit such characteristics, normality is the only critical assumption involved. In addition, since screening tends to reduce the number of poor scores for each criterion while scores at the upper extreme seem intuitively to be limited, the normality assumption may not be too misrepresentative of the proper distribution. Figure 4 hypothetically illustrates this effect of the screening process on the criterion scoring distributions. The role of these probability distributions in criterion combinations is shown later in this section (pp. 49,50).

Before individual scores are assigned to each application being evaluated, criterion weights, where appropriate, must be established

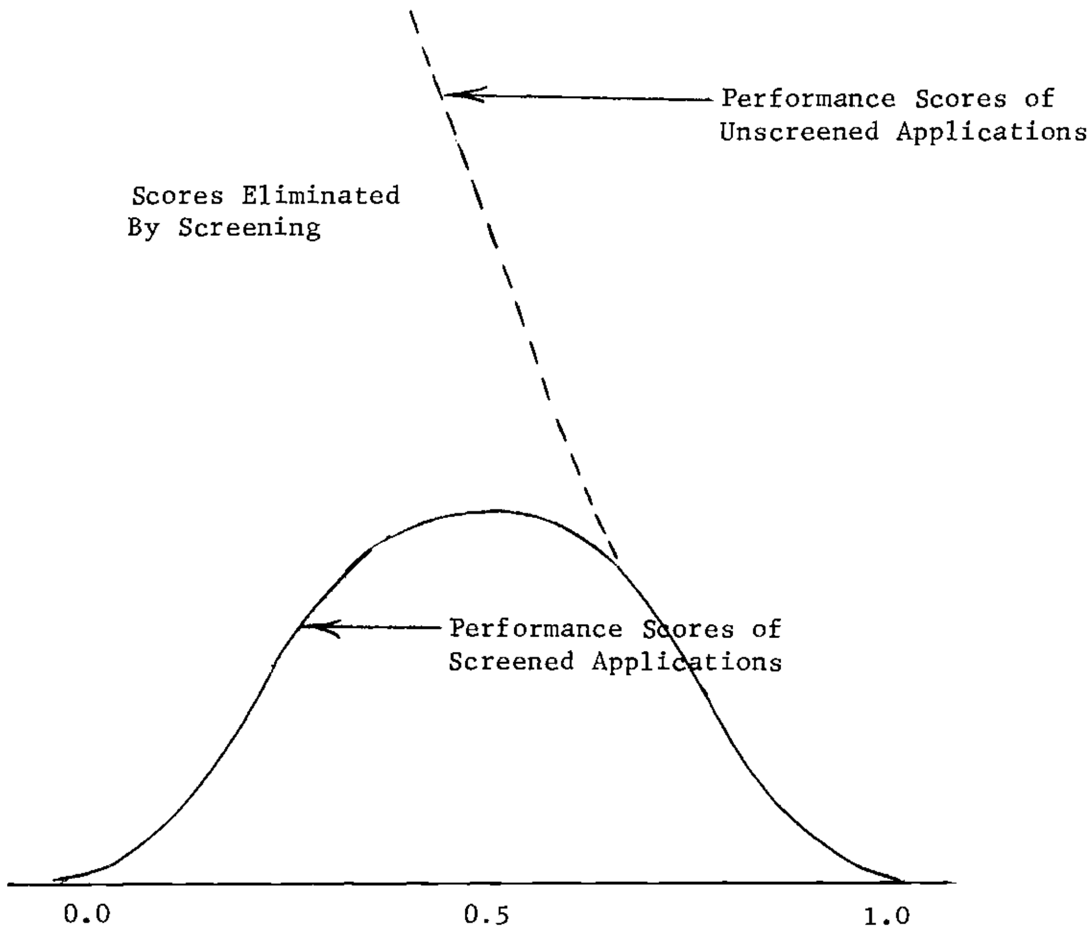

Figure 4. Hypothetical Scoring Distributions for Screened and Unscreened Applications.

using one of the weighting methods discussed earlier. Such a method establishes the linear coefficients for the additive combinations shown below:

$$C_{12} = W_{121}\ C_{121} + W_{122}\ C_{122}$$

and

$$C_0 = W_1\ C_1 + W_2\ C_2$$

where the C's designate the scores for each criterion as shown on the hierarchy tree in Figure 3 and the W's represent the coefficients of importance of each criterion relative to the others in its criterion subset. The subscript on each "C" indicates the specific criterion referred to, as shown in Figure 3.

Earlier, it was noted that in order for the assigned weightings to be realized in the scoring model calculations the distributions of all scores for criteria within each subset must span the same range and be similar in form. In the calculation of C_{12}, shown above, such conditions are satisfied by the original assumption that all basic criteria have standardized, normal distributions. However, before the calculation of C_0 can be performed satisfactorily, the performance score distribution of C_1 must be identified. To do this, one must first look at the distributions of C_{11} and C_{12}. C_{11} has a standardized normal distribution by the original assumption. C_{12} because it is a linear combination of two independent normally distributed functions is also normally distributed with a mean, $\mu_{12} = W_{121}\ \mu_{121} + W_{122}\ \mu_{122}$ and a variance,

$\sigma_{12}^2 = W_{121}^2\, \sigma_{121}^2 + W_{122}^2\, \sigma_{122}^2$. Such a distribution could then be standardized, and made consistent with C_{11} by the transform

$$C_{12}' = \frac{C_{12} - \mu_{12}}{\sigma_{12}} \sigma_S + \mu_S$$

where:

C_{12} = the score resulting from the linear combination of the scores of C_{121} and C_{122}.

and

C_{12}' = the adjusted score of C_{12} which is representative of a normal distribution having $\mu_s = 0.5$ and $\sigma_s = 0.1938$.

The combination of C_{11} and C_{12}' is then obtained by multiplication.

$$C_1 = C_{11} \cdot C_{12}'$$

Since it is known that the product of two normally distributed independent random variables also approximates a normal distribution with a determinable mean and standard deviation, the mean and variance of C_1 can be found to be

$$\mu_1 = \mu_{11} \cdot \mu_{12}$$

and

$$\sigma_1^2 = \mu_{11}^2\, \sigma_{12}^2 + \mu_{12}^2\, \sigma_{11}^2$$

Hence, with these characteristics known, the distribution can again become standardized by using the transform

$$C_1' = \frac{C_1 - \mu_1}{\sigma_1} \sigma_s + \mu_s$$

The resulting standardized distribution could then be combined with the standardized distribution of C_2 without compromising the integrity of the weightings W_1 and W_2.

C_0 could then be determined and standardized in a similar manner, and would be used as the overall measure of effectiveness improvement to be obtained by implementation of each application. The ratio of development cost to the overall effectiveness value, C_0, would form the cost/effectiveness measure for each application to be used in the application selection and priority ranking.

Although the described calculations are relatively straightforward, their simplicity is largely due to the assumption of normality for all criterion performance level distributions and the avoidance of importance weightings on multiplicative criteria. Where such assumptions are unacceptable to the HIS planning team, the distributions of the results of criterion combinations can be found by Monte Carlo sampling techniques using computer aided calculations.

Evaluation Process

In addition to the considerations regarding the criteria, detailed structure, and mathematics of the model, both the selection of evaluators and the specific procedures used to obtain and convert their individual evaluations into a consensus score are critical aspects of the methodology design.

Selection of Panel Members

Because the final results and recommendations of the entire priority setting process must be presented to a higher executive level as inputs to the actual decision, the executive level should participate in if not dictate the selection of panel members. At the same time, however, efforts should be made to assure a reasonably unbiased mix of participants with expert knowledge in all aspects of the subject activities. The basic membership of the panel should include representatives of the administration, the medical staff, and the computer systems staff. Additional representation of hospital-wide planning staffs and hospital departments to be specifically affected should be traded off against the increasing complexity of consensus formulation with increasing numbers of participants.

Department heads and other individuals highly knowledgeable in specific information subsystems should form subcommittees to evaluate the relative merits of mutually exclusive applications affecting their own functional areas and to report their analysis and recommendations as inputs to the primary HIS planning committee.

Evaluation Procedures

Once the evaluators have been selected and have participated in both the model development and the application screening and analysis activities described in this chapter, the specific procedures for their use of the model in evaluating the candidate applications must be developed and accomplished. Although free discussion of the criteria, model structure, and application analyses should be encouraged throughout the model development and application description phases to promote an exchange of viewpoints and considerations among panel members, collaboration and discussion regarding direct evaluations should be avoided. The permission of such discussion during the final weighting and scoring activities might bias the results in favor of the most prominent or persuasive member's evaluations. This is the primary reason for requiring individual scores from each evaluator rather than obtaining a committee consensus through discussion, debate,and persuasion.

The criterion weighting is determined first using a method selected from those previously listed. Next, each evaluator is given a scoring sheet such as the one shown in Figure 5 for the previously described example model. Each evaluator then evaluates the applications by each criterion and places his relative score in the indicated space. Because most criteria require relative evaluations among applications, each criterion should be analyzed against all applications before the next criterion is considered.

After all individual scores have been assigned, they should be analyzed to study how much scoring variance exists among individual evaluators. If little variance is present, the scores should be averaged and the median scores then used in calculating the effectiveness value for each application. If, however, considerable evaluator variance is found, it may be necessary to reconsider the criterion scores in the areas having the highest variance. A method of such iterative evaluation by panels of experts, the Delphi approach, has received considerable notice in the literature (5, 9, 38). Although time consuming

DESCRIPTION OF APPLICATIONS: A. Pharmacy B. Radiology #1 C. Radiology #2 D. Dietary				
Criterion/Factor	Ratings A	 B	 C	 D
Need for Improvement				
Timeliness				
Content				
Changes in Operating Cost				

Figure 5. Example Application Scoring Sheet.

and cumbersome to administer, the approach offers the advantages of obtaining explanations of extreme scores and allowing each evaluator to review the average scores and explanations before rescoring. Again, care is taken to avoid bias due to a prominent or persuasive evaluator; the names of the scorers are not identified with the explanations or scores. Because of the time requirements of the Delphi approach and the large number of scores assigned in the HIS evaluation, the technique appears to be impractical for wide-scale use in rescoring the applications. However, where there are only a few critical scores having wide evaluator variance, the use of Delphi may be warranted. Identification of such critical criterion scores is discussed in the sensitivity analysis section of this chapter.

Selection Among Mutually Exclusive Applications

Because several alternative applications for the same information subsystem and function may survive the screening process and enter the scoring model evaluation, a selection among such mutually exclusive applications must be made before priority rankings can be established among independent applications. Although it may appear logical to base such a selection solely upon a comparison of the two or more applications' cost/effectiveness ratio's, the ratio selection rule often results in suboptimum choices, since it neglects to consider the value of the incremental differences in both costs and benefits of the applications (13, 20, 36). A more proper selection method is based upon an analysis of the "incremental investment," representing the differences between the two applications. The incremental cost/

effectiveness ratio, found by dividing the cost differential by the effectiveness differential, is compared to a maximum acceptable cost/effectiveness ratio, the MAR, to determine the acceptability of the incremental investment. For example, two applications, A and B, having development costs, C_A and C_B ($C_A \geq C_B$) and effectiveness values, E_A and E_B, would form an incremental application A-B with a cost/effectiveness ratio of $\frac{C_A - C_B}{E_A - E_B}$. Application A would then be selected if the incremental ratio were greater than zero but less than the MAR. Application B would be selected for ratio values less than zero or greater than the MAR. If the ratio were zero, the application with the greater effectiveness value would be chosen. For more than two mutually exclusive applications, an incremental analysis is first made for the two proposals with the lowest development costs. The application selected from the initial analysis would then be similarly compared with the next lowest cost proposal. Such iterations would continue until the list of mutually exclusive applications is exhausted.

Although theoretically straightforward, in practice the incremental analysis method is complicated by the difficulty of establishing the MAR. Since the effectiveness rating is relative only to those applications being evaluated by the specific scoring model in use, no universally acceptable maximum ratio can be established. Instead, the incremental ratio should be compared with the cost/effectiveness ratios of other applications known to be acceptable. Such comparisons would build sufficient insights to decide upon the acceptability of the incremental application and hence would allow for selection among the mutually exclusive proposals.

Priority Ranking of Candidate HIS Applications

Fortunately, the difficulties with the ratio selection method for mutually exclusive alternatives do not apply to the problem of HIS priority ranking. Since all applications elligible for priority assignments are substantially independent, the selection of one at a high priority does not preclude the later implementation of any other; only the order or implementation is involved. For that reason, the assignment of priorities according to increasing cost/effectiveness ratios will lead to the maximization of benefits attained for development dollars expended assuming a constant proportionality between development costs and development time. As mentioned previously, this is true only if the time value of benefits is not considered. Further discussion regarding these assumptions is presented later in this chapter (p. 60).

Although the cost/effectiveness values do provide an overall evaluation of each application and a logical method of ranking them for implementation, the primary purpose of the scoring model should usually be not to rigidly fix the implementation schedule, but rather to systematically structure the comprehensive analysis of all factors relevant to priority determination and to sharpen the insights, intuition and judgement of the decision makers. In this regard, the numerical scoring model results serve only as the basic foundation and framework for the determination of the implementation schedule, while the final recommendations are made by the committee after analysis of both the scoring model results and those considerations which are omitted by the model limitations. These considerations are discussed further in

Chapter V.

Sensitivity Analysis

The purpose of sensitivity analysis of the scoring model results is to determine if small changes in either the structure or scoring of the model would affect the resulting evaluations and priority rankings. It is a useful part of the priority setting methodology for two reasons. First, it is a test of the scoring model's ability to represent the appropriate importance relationships among the criteria as perceived by the planning committee. If the model results turn out to be highly sensitive to criteria deemed relatively unimportant or to be insensitive to highly important criteria, the model structure or criterion weightings should be adjusted to better represent the desired importance of each factor. The second useful aspect of sensitivity analysis involves a form of significance testing among closely rated applications. If two applications receive close but different overall cost/effectiveness ratings, it may be important to know whether or not the difference is significant. In such a case, if small changes in various criterion scores resulted in changes in the ranking of the two applications, their differences would be considered relatively insignificant and their order of implementation would be of little consequence. Such information should be valuable to the planning team or other decision makers in interpreting the significance of the cost/effectiveness ranking and converting it into an actual implementation schedule.

The primary benefits available from study of scoring model results can be obtained through the careful design and review of a relatively simple sensitivity analysis as described for the model results of the trial application in Chapter V. Such an analysis would include determinations of the effects of changes in each criterion's score on the overall cost/effectiveness ratio, as well as calculations of the changes in each individual criterion's scores necessary to cause a reversal or change in the priority rankings. These rank-reversing score changes could then be mathematically related to the variation of criterion scores among the evaluators in order to assess the probability of their occurrence due to further consideration and convergence of the scoring panel. In this way, those critical criteria which warrant further analysis could be identified and pursued using the Delphi rescoring technique described previously. Further discussion of the design of sensitivity analysis and the conclusions to be drawn from them are included in the following chapter's description of the trial application of the methodology.

Scoring Model Maintenance and Reuse Over Time

As discussed in Chapter III, the described priority setting methodology should be reapplied periodically throughout the HIS development process. Each successive evaluation should be based upon the existing overhead system at the time of evaluation and is applicable for only a relatively short planning horizon of from one to three years. At the end of such a period, the availability of new applications, substantial changes in the system overhead, or changes in the need for improvements in the hospital would warrant a reassessment of priorities and an update of the implementation schedule.

Fortunately, each evaluation iteration does not require a complete redesign of the scoring model. If properly developed initially, the criterion hierarchy and descriptions should undergo little or no change throughout the HIS development. Furthermore, continued use of the model should allow certain refinements in its application. One such improvement would involve the reestimation of criterion performance distributions based upon the results of the previous evaluations of other HIS applications using the same scoring model.

Although changes in the criteria themselves would be expected to be infrequent, each reapplication of the scoring model should involve a reweighting of the criteria to reflect any changes in their relative importances due to shifts in program emphasis. Of course, all applications would have to be rescored for all criteria using updated descriptions of their expected performance levels and cost estimates.

Potential Model Improvements

In the previous sections of this chapter, the guidelines and considerations to be followed in developing and using a scoring model for HIS priority setting have been described and explained. For example and demonstration, the use of these procedures have been further illustrated in the trial application of the methodology presented in Chapter V. The use of these guidelines to obtain an optimal implementation schedule is based, however, on certain simplifying assumptions which may not be realistic in all cases and which should be of concern to future users of the methodology. One such assumption requires that development costs and development times must maintain a constant proportionality for all applications. This means that if one application costs twice as much to develop as another it should also require twice as much development time. Since the applications' development costs in any one planning horizon are determined primarily by the salaries of the development staff and if purely sequential implementation is assumed, this assumption appears viable. However, if the incremental equipment costs for a particular application is disproportional to the staff costs during its developmental period, the cost-time proportionality also changes and the priority rankings resulting from the scoring model would not be directly applicable.

An example of such a situation is described below:

Application	Development Time	Development Cost	Benefits per Year
A	1 year	$1000	100b
B	1 year	$ 500	50b

Although both of the two applications have cost/effectiveness ratios of 10.0, and hence, identical scoring model rankings, the order of their implementation can be shown to be significant.

Figure 6 illustrates the cash and benefit flows for the two possible implementation schedules, assuming that benefits begin accruing only after full implementation is accomplished. If application A is implemented first, the cumulative benefits at the end of the third year equals 250 units of effectiveness, while the alternative schedule

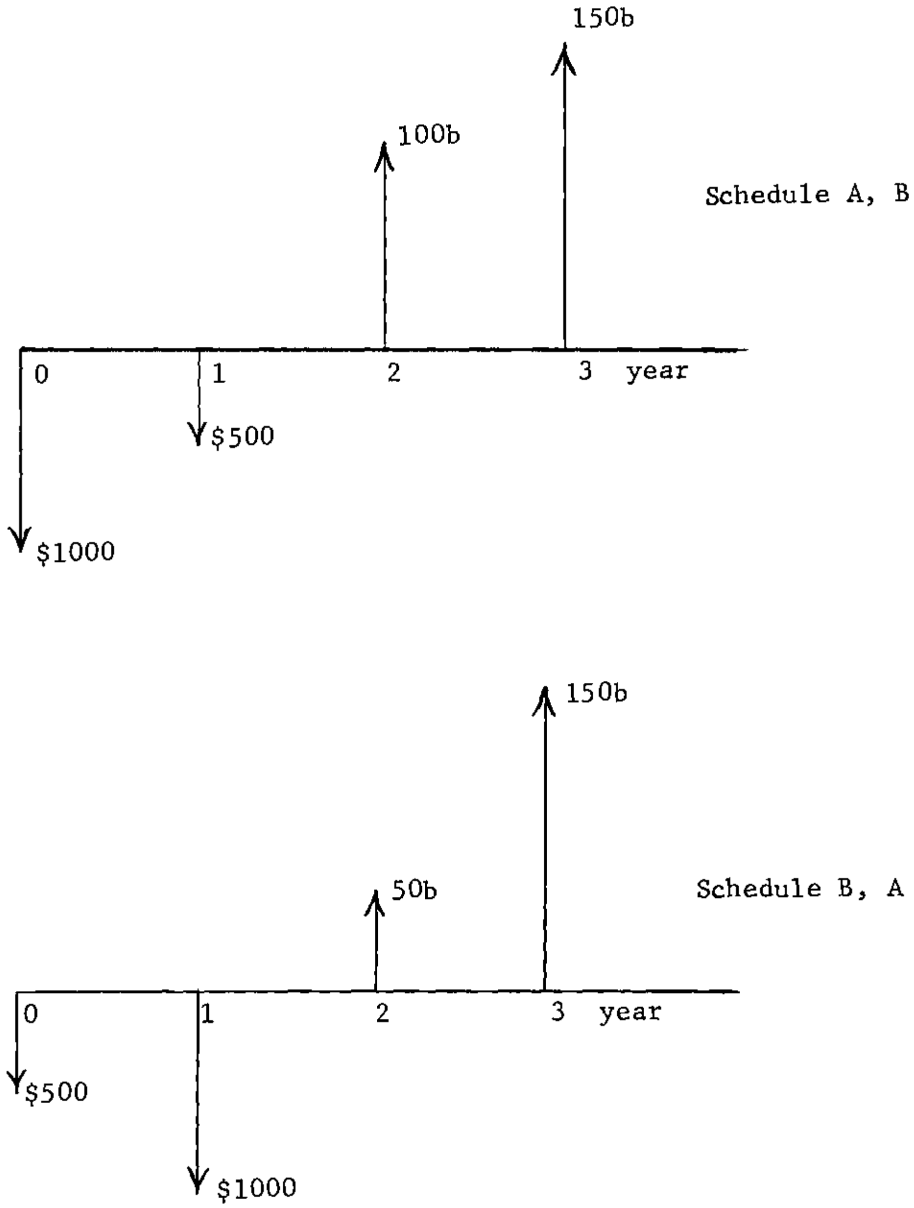

Figure 6. Cash and Benefit Flows for Alternative Implementation Schedules.

would yield only 200. Therefore the order of implementation of the two applications would appear significant. For this reason, the planning committee should note where the constant proportionality assumption appears untenable and should adjust the scoring model results appropriately by favoring projects with higher than average cost to time ratios.

Even where the cost-time proportionality is constant, consideration of the time value of benefits may affect the application priorities. If application A in the above analysis were assigned a development time of two years rather than one, the proportionality assumption would be met and the accumulated benefits after the fourth year would be 250 for either alternative. However, if the value of future benefits were discounted, say 10 percent per year, in a manner similar to that used in time value of money considerations, a present worth analysis would allow the cumulative value of benefits at the end of the fourth year for each alternative schedule to be calculated as follows:

$$PW_{A,B} = \frac{100}{(1.10)^3} + \frac{150}{(1.10)^4} = 177.6$$

and

$$PW_{B,A} = \frac{50}{(1.10)^2} + \frac{50}{(1.10)^3} + \frac{150}{(1.10)^4} = 181.34$$

Therefore, since the objective of the priority schedule is to maximize the value of the benefits obtained per development dollar, and since the flow of development costs does not vary with the choice of the schedule, the implementation of project B first is indicated.

Although no procedure for directly considering discounts for future benefits is incorporated into the HIS priority methodology, the planning committee should make such considerations subjectively and adjust the implementation accordingly. The development of a scheme for the direct inclusion of disproportionate cost-time relationships and benefits discounts within the analytical portion of the methodology is recommended as a fertile area for additional research.

CHAPTER V

DEMONSTRATION OF METHODOLOGY

As discussed in Chapter III, the purpose of the methodology demonstration is to explain better how the general guidelines and procedures proposed in the methodology are to be followed in designing and using a scoring model to establish HIS priorities. The demonstration was accomplished by using members of the HIS planning committee of the Medical College of Georgia to design and use a scoring model for evaluating several applications to a mock hospital's real-time information system and to determine their implementation priorities.

Description of Mock Hospital

Because no available hospital was far enough advanced in their HIS planning to require priority determinations among alternative applications at the time of this research, it was decided to use a mock hospital in the demonstration of the methodology. The hospital was designated as a 400 bed non-teaching facility offering a typical mix of medical and surgical services as summarized in Figure 7.

It was assumed that the hospital had previously developed a substantial batch-mode computer capability and currently had operational applications in payroll, patient billing/accounts receivable, general ledger, and accounts payable. The hospital had developed the batch-mode system using an in-house approach and maintained a large computer systems staff with which to begin additional developmental

A. INPATIENTS

Beds:	400
Occupancy:	90 percent
Census:	360
Admissions:	16,500

Average Length of Stay: 8 days

Patient Mix:

Medical	36 percent
Surgical	31 percent
OB-GYN	14 percent
Pediatric	19 percent

ICU/CCU: 20 beds

B. OUTPATIENTS

General Clinic:	25,000 visits/year
Emergency Room:	9,000 visits/year
Specialty Clinics:	20,000 visits/year
Total	54,000 visits/year

Figure 7. Summary of Mock Hospital Services.

efforts. In addition, it was assumed that the hospital had previously undertaken a feasibility study which had established the cost-justification for a real-time, patient-oriented information system and had generated a full commitment for such a system's development. It was assumed that the decisions regarding the basic type of system to be designed and the initial selection of the overhead equipment had been determined prior to the application of the methodology. As mentioned in Chapter III, any specific equipment or software which was needed by all or most of the candidate applications was considered part of the overhead system.

The system was to have cathode ray tube displays and keyboard input devices and printers in each remote, on-line terminal. Initially, a minimum number of such terminals were to be placed in the nursing units, the medical record department, and other areas having substantial interaction with a large number of information functions. These initial terminals are considered a part of the overhead system and only the additional terminals required by the implementation of specific HIS applications are apportioned to the application development. The operating software for routine use of the terminals as well as the development of the file structure for the individual patient record was assumed to have been previously decided and, hence, independent of the sequence of implementation of the candidate applications.

In addition to a description of the basic HIS structure planned for the mock hospital, the descriptions of the current operation and performance of the information subsystems were developed to provide a basic profile of workloads, performance levels and general procedures.

These subsystem descriptions were limited to the areas of laboratory, diagnostic radiology and pharmacy for the purposes of the demonstration. The summary descriptions used in the demonstration are included as Appendix A.

These subsystem descriptions contain only the basic information needed for the priority setting evaluation; they do not contain the more detailed estimates of transaction requirements and volumes needed in determining the technical feasibility of the applications.

Both quantitative and qualitative assessments of present information subsystems are presented in the descriptions. Much of this information would normally be obtained from the users of the subsystems.

Candidate HIS Applications

The subsystem descriptions serve as the basis against which improvements offered by each HIS candidate application are measured. In general, each measure or indicator of subsystem performance is estimated for each application assuming the application's successful implementation. These estimations are obtained by detailed analyses of the system response times, transaction volumes and various other determinants. It is assumed that such information would be acquired in the earlier screenings and tests of application feasibility. In the present evaluation methodology, the planning team would simply review such information for completeness and possible discrepancies before summarizing the data for use in the priority determination. As in the subsystem descriptions, subjective comments are included in the application descriptions to reflect the evaluation of each application by its potential users in the various hospital departments.

Although the application descriptions used in this demonstration include the basic types of performance information needed for priority evaluation, they are not intended to be adequate for developmental and systems design purposes, nor do they represent realistic applications for any particular hospital. Summary descriptions of the demonstration applications are presented in Appendix B. They include two alternative HIS plans for the laboratory, one for pharmacy, and one for radiology. The performance and cost estimates as well as the automated procedures discussed in these descriptions are based primarily upon information regarding previously planned HIS applications presented in the literature (6, 42), and are not necessarily appropriate for any particular hospital which might use this methodology. Such estimates would have to be developed by each institution performing HIS planning.

HIS Planning Team

In order to demonstrate the use of the developed methodology, members of a planning committee for HIS activities at the Medical College of Georgia agreed to design and utilize a scoring model to evaluate the candidate applications proposed for the mock hospital and to determine their implementation priorities. The evaluation participants included a hospital administrator, a physician, a computer systems analyst, two health systems engineers and the director of hospital research and development. Each participant had considerable knowledge in both hospital operations and hospital information systems, yet each presented a different combination of experience and expertise. It was decided to exclude participation of individuals associated with only specific aspects of the information system, such as representatives from each department involved directly in the applications, for three reasons. First, the availability of such individuals for the demonstration was limited; second, their participation would increase the size of the evaluation team making logistical arrangements more difficult; and finally, their bias toward their particular subsystem might affect the evaluations. Had the demonstration involved the planning of HIS activities in an actual hospital, such individuals would have been asked to supply evaluation inputs to the planning committee as described earlier.

The planning team, working with the author in a series of five meetings, developed a scoring model appropriate for evaluation of applications for the mock hospital. The four candidate descriptions were then presented to the team for evaluation using the developed scoring model. The scoring results were used to compute an initial implementation schedule for the applications and were reported back to the evaluation team. Finally, the team was asked to assess the feasibility and value of the methodology as used in the demonstration and to evaluate its various aspects. The remainder of this chapter presents a description of the scoring model developed by the planning team and the results of its application. A discussion of the participants' evaluation of the methodology itself is presented in Chapter VI.

Description of the Scoring Model

The development of the scoring model by the HIS planning team underwent several iterative and overlapping phases. Once the specific purpose of the scoring model was established (i. e., to measure the expected relative improvements in hospital effectiveness due to application implementation) the team began to identify and select the criteria relevant to such a measure. Also, the logical interrelationships of the criteria in the evaluation process were established. At the same time, descriptions of the criteria were developed and the scoring functions to be used for measurement relative to the criteria were formulated. The general distribution of performance scores for each criterion was then estimated for all potential applications and the relative weightings of all criteria was determined.

During this development process, the guidelines suggested in Chapter IV were followed and each aspect of the model design and structure was examined for its possible effect upon the resulting evaluation.

Criterion Selection, Description and Hierarchy Determination

Initially, the measurement of improvements in effectiveness was divided into the three areas of (1) direct improvements in the value and use of the information subsystem and their effects on the hospital; (2) indirect considerations, or improvements in such things as hospital image and employee morale; and (3) changes in the operating costs of the subsystems. The hierarchy tree shown in Figure 8 was then developed to relate individual criteria to the three criterion groupings. The summaries of the criterion descriptions, scoring functions, and per-

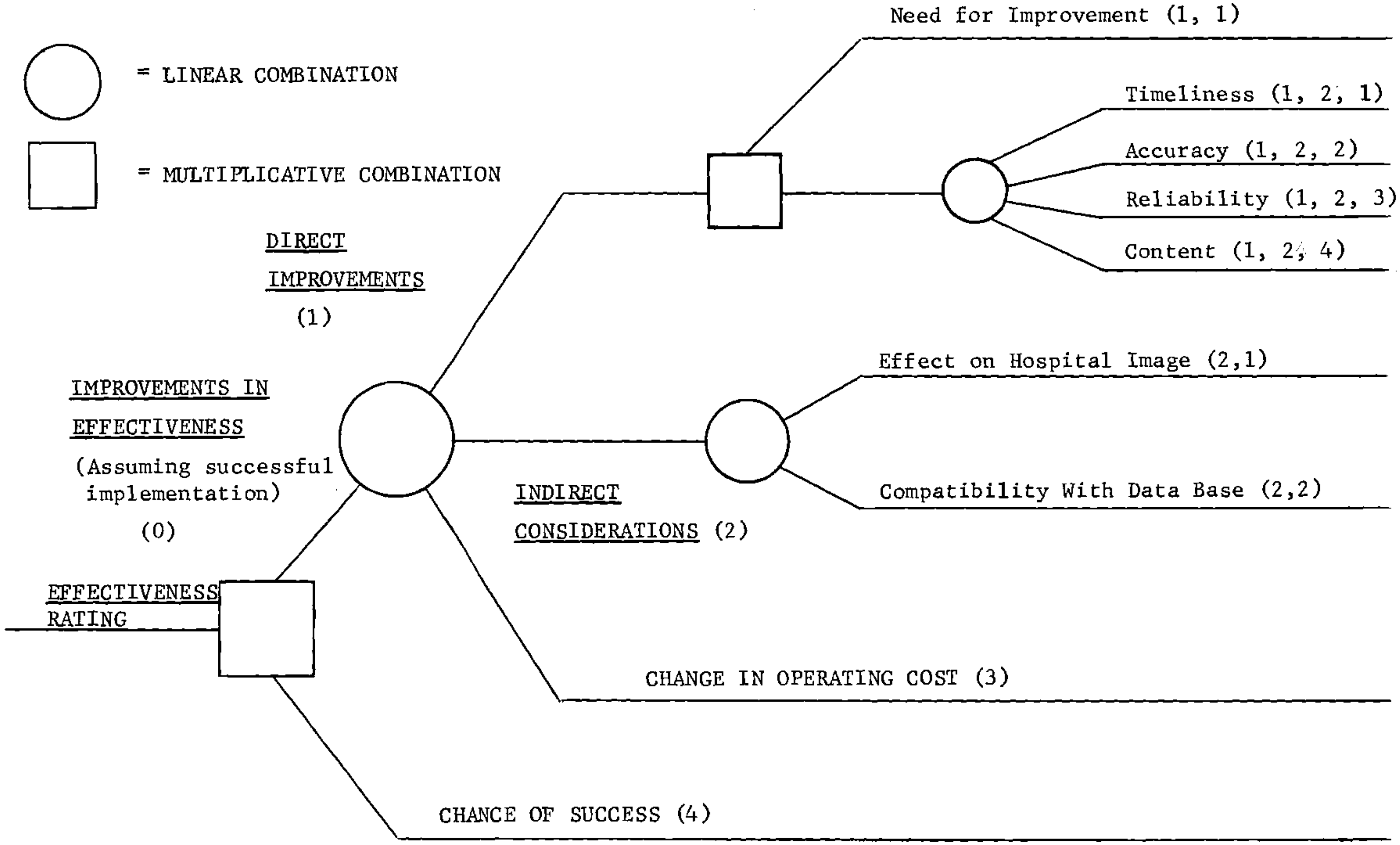

Figure 8. Demonstration Criterion Hierarchy.

formance level distributions used in the demonstration are presented in Appendix C.

It was decided that the value of direct improvements could best be represented by a combination of criteria concerning both the need for improvements and the actual improvements themselves. Intuitively, a multiplicative combination was indicated, as the need factor should directly discount the value represented by the measure of actual improvement. Further, four individual criteria were selected as being additive factors in the measurement of direct improvements. As shown on the hierarchy tree, the four direct improvement criteria are measures of the relative effects of changes in timeliness, accuracy, reliability, and content on the value and use of the information involved in each HIS application.

The measure of the indirect improvement considerations, for the purposes of the demonstration, involved criteria for the effect of the HIS application on the hospital's image to both the public and the hospital staff and the degree of compatibility that the data generated would have with the development of a management information system and data bank. It was agreed that this area of criterion selection is particularly dependent upon the hospital's unique environment and that the representative criteria proposed here would probably be supplemented or replaced by various others in most model designs.

The measure of improvements in effectiveness due to changes in operating cost was viewed to be a direct function of the changes themselves. It was assumed that estimates of such costs would be generated from previous phases of the planning activities.

The measure of chance of success was also considered as a determinant in the evaluation and was given a multiplicative relationship with the aggregate of all other criteria. For the purposes of this evaluation, chance of success was viewed as the subjective probability in the minds of the evaluators that the application would be implemented successfully and accepted by the hospital staff and patients within the estimated development time indicated in the application descriptions. Although this assumption ignores the consideration of varying degrees of success possible with relation to each criterion, its use in the model was deemed necessary by the planning team to represent the risks and difficulties associated with each application.

Criterion Scoring Functions and Distribution Estimates

It was decided by the planning committee that the subjective or direct assessment type of scoring function described in Chapter IV would be required for all but the operating cost criterion. For example, although the estimated response times and cycle times for information outputs are presented as quantitative inputs to the timeliness criterion, the effect or value of a change in such performance levels is highly dependent upon the nature of the information involved and therefore varies among information subsystems. Accordingly, the effect of a 20 percent improvement in response times for inpatient drug requests might be much greater than a similar reduction in the cycle time for outpatient lab reports, if the lab reduction was insufficient to return the results to the patient during the original visit. However, if the 20 percent laboratory cycle time reduction was sufficient to reach a "threshold" which would allow the patient and doctor to receive the laboratory findings during the initial visit, the value of the change might be far greater than the corresponding one in drug response times. Since such thresholds and the importance of similar changes vary significantly among subsystems, a single mathematical scoring function is not feasible for the measurement of this type of criterion overall candidate alternatives. Other criteria in the model, those measuring information content, hospital image and data base compatibility, are even more subjective in nature, having fewer quantitative inputs, and also require the direct assessment scoring functions.

Another consideration necessary in the design of scoring functions is in the selection of a continuous or an interval scoring scale as discussed in Chapter IV. In the development of the demonstration scoring model, the evaluation team had difficulty in establishing such interval descriptions because of disagreements in the interpretation of their semantics. After several attempts at restructuring the descriptions, it was decided to utilize a continuous scale, subjective scoring function with only the end points and one midpoint identified by narrative descriptions as shown in Appendix C. As a result, the score variances among evaluators were found to be high. Although the high variance due to each evaluator's individual interpretation of the scale should have little impact on the overall rankings if the relative differences between scores for each application by each evaluator are reasonably consistent, it tends to confuse any indepth analysis of elemental scores.

The criterion measuring improvements in effectiveness due to changes in the operation costs was assigned a scoring function which was directly related to the cost changes themselves and therefore required no scoring by the evaluators. It was assumed that the cost determinations had been made previously and had been reviewed and approved by the committee.

For each criterion selected in the demonstration a scoring range was set up with a minimum score of 0.0 and a maximum of 1.0. The range was identical for each criterion so that the mathematics required to maintain the integrity of the assigned importance weightings of the criteria could be simplified. Further, because of the absence of prior information regarding criterion scores for HIS applications, the scoring distributions for all criteria were assumed normal with a mean of 0.5 and a standard deviation of 0.1938. With such a distribution, the probability is .99 that any random score will fall within the established scoring range.

Although the assumed distribution was chosen to facilitate the combinatorial mathematics of the model, its general form seemed reasonable under the assumption of prescreened applications as described in Chapter IV. By using such a screening process, the majority of the poorer applications would be eliminated leaving a generally bell-shaped curve for the distribution of post-screening candidate alternatives as was shown in Figure 4. The assumed mean of 0.5 for all criterion distributions is somewhat arbitrary, but was made more acceptable by assigning the "zero improvement" value on each criterion scoring function to be appropriate, relative to a mean score of 0.5.

In addition, the end point descriptions were selected to have connotations appropriate for encompassing 99 percent of the scores. The scoring functions, scoring guide descriptions and assumed distributions for the demonstration criteria are presented in Appendix C.

It should be noted that in the chance of success scoring function, the scoring range goes from 0.0 to 1.0 even though the range of probabilities for screened applications is only from 0.5 to 1.0. This adjusted range indicates that the screening process eliminates all applications having a less than 50 percent chance of success and provides a form of compensation for the risk aversion expressed by the planning team.

Criterion Weighting

After the criteria were selected, defined, and related in the hierarchy, the method of weighting their relative importances was selected and applied. Any one of the weighting techniques discussed in Chapter IV would have been sufficient for the relatively simple weighting requirements of the demonstration model. The weighting method used in the demonstration was adapted from the successive comparison method.

Weightings were required for the criteria in each additive grouping of the hierarchy as shown in Figure 8. Each evaluator was asked to assign weightings to the criteria in each grouping and record them as illustrated in Figure 9. The evaluators were provided with the following instructions:

Considering each criteria subset independently,

1. Rank each criterion in the order of relative importance

I. Direct Improvement Criteria Subset

Criterion	Rank	Rate	Weight
Timeliness	1	1.0	.373
Accuracy	3	1/2	.187
Reliability	2	3/4	.280
Content	4	3/7	.160
Total	-	2.68	1.00

II. Indirect Improvement Criteria Subset

Criterion	Rank	Rate	Weight
Hospital Image	2	1/3	.25
Data Base Compatibility	1	1.0	.75
Total	-	1.33	1.00

III. Overall Effectiveness Criteria

Criterion	Rank	Rate	Weight
Value of Direct Improvement	1	1.0	.461
Indirect Consideration	3	1/2	.230
Operating Cost	2	2/3	.309
Total	-	2.17	1.00

Figure 9. Example Criterion Weighting Form.

(from 1 to n, where n = the number of criteria).

2. Assign a rate of 1.0 to the criterion ranked first (most important).
3. Compare the second ranked criterion with the first and assess its relative importance as a fraction of the first.
   a. If both are of equal importance, give the second a rating of 1.0 also.
   b. If the first is four times as important as the second, assign a rating of 1 (1/4) = 1/4 to the second.
4. Compare the third ranked criterion with the second and assess its relative importance as a fraction of the importance of the second. Multiply the rating assigned to the second criterion by this fraction and assign the resultant product to the third criterion.
5. Repeat this procedure for all successive pairwise comparisons until all criteria in the subset have been assigned ratings.
6. Add the ratings assigned to all criteria in the subset and divide each one by the computed sum. This will convert the ratings into normalized weights which will sum to one.

The weightings were assigned at the beginning of the application evaluation session, before any of the applications had been scored. Therefore, the assigned weightings were constant for all applications evaluated. The weights served as the linear coefficients used in each of the additive combinations as explained in the discussion of scoring model mathematics in Chapter IV.

Scoring Model Results

After the weights were established, the descriptions of both the hospital subsystems and the candidate applications were again reviewed by the evaluators. Each evaluator was then asked to assign scores to each application for each criterion as he felt appropriate. Scores were assigned to all applications for a certain criterion before the next criterion was considered so that the scores would better reflect the relative evaluations among applications. Although four of the six planning team members recorded their evaluations at the same time and place, they did not confer with one another so that their scores were assigned independently.

The individual weights and scores were then averaged to yield the scores shown in Figure 10. The scores for the operating cost criterion were determined directly from cost estimates and the operating cost scoring function and hence were not considered by the evaluators. The average scores and weights, together with the criterion performance distribution estimates and the hierarchy relationships were used to calculate a total improvement in effectiveness rating for each application using the mathematics described in Chapter IV. The effectiveness ratings resulting from these calculations are shown in Table 1. These effectiveness values were then divided into the development cost estimates to determine the cost/effectiveness ratings and the initial priority rankings also shown in Table 1.

Selection Between Mutually Exclusive Laboratory Applications

Since only one of the two proposed laboratory applications can

DESCRIPTION OF ALTERNATIVES:

A. Laboratory--Inpatient Only

B. Laboratory--Inpatient and Outpatient

C. Radiology--Diagnostic Only

D. Pharmacy

C	CRITERION/FACTOR	WT.	RATINGS A	B	C	D
C_1	I. Value of Direct Improvement	.453	-	-	-	-
C_{11}	A. Need for Improvement	-	.600	.825	.667	.617
C_{12}	B. Direct Improvement	-	-	-	-	-
C_{121}	1.Timeliness	.288	.675	.833	.700	.475
C_{122}	2.Accuracy	.242	.783	.783	.733	.700
C_{123}	3.Reliability	.252	.667	.783	.733	.617
C_{124}	4.Content	.217	.542	.550	.625	.725
C_2	II. Indirect Considerations	.235	-	-	-	-
C_{21}	A. Image	.456	.650	.808	.753	.533
C_{22}	B. Data Base Compatibility*	.544	.680	.640	.600	.630
C_3	III. Operating Cost**	.312	.5	.41	.18	.78
C_4	IV. Chance of Success	-	.717	.692	.642	.767

*based upon 5 scores only

**scores predetermined by objective analysis

Figure 10. Average Criterion Scores and Weightings.

Table 1. Initial Cost/Effectiveness Calculations.

	Applications			
	Lab #1	Lab #2	X-Ray	Pharmacy
Development Cost	\$83,000	\$128,000	\$152,000	\$186,000
Effectiveness	1.059	1.346	.907	1.156
Cost Effectiveness Radio $\left(\frac{\text{cost}}{\text{effectiveness}} \times \frac{1}{1000}\right)$	78.38	95.10	167.59	160.90
Ranking	1*	2*	4	3

*Since the two laboratory applications are mutually exclusive, only one would be included in the final ranking.

be implemented, they are said to be mutually exclusive alternatives. The "best" application from such a mutually exclusive set must be selected before overall rankings can be established among the other independent applications. As discussed in Chapter IV, this selection should be done using an analysis of the incremental investment based on the differences in both costs and effectiveness values between the two laboratory applications. Only if the cost/effectiveness ratio of the incremental application is judged to be acceptable, should the more costly proposal be selected. Such an incremental analysis for the two laboratory applications is presented in Table 2.

In Table 2 it is shown that although the Laboratory #1 application (inpatient only) received the lower cost/effectiveness rating, because the incremental cost/effectiveness ratio of 156.79 is less than the ratios shown in Table 1 for either the radiology or the pharmacy applications, the more costly (inpatient and outpatient) laboratory application should be selected. This conclusion is based on the assumption that the pharmacy and radiology applications have acceptable cost/effectiveness values (i. e. have ratios less than the maximum acceptable ratio).

Sensitivity Analysis

Sensitivity analysis of several types was performed on the results of the application evaluations. First, an analysis was performed to test the sensitivity of the cost/effectiveness ratios to small changes in scores for each criterion. The results, displayed in Table 3, were studied by the model evaluators to ascertain that the relative impacts of the criterion changes were consistent with the

Table 2. Incremental Analysis of Laboratory Applications.

Application	Development Cost	Effectiveness	C/E Ratio
A. Laboratory #1	$ 83,000	1.059	78.38
B. Laboratory #2	128,000	1.346	95.10
B-A. Incremental	$ 45,000	.287	156.79

Table 3. Sensitivity of the Cost/Effectiveness Ratings Due to Changes in the Average Scores of Specific Criteria.

Assumed: Development = $100,000
All initial scores = 0.5

Criterion		Percent Change in Criterion Score: 10% E'	10% C/E	10% C/E % Change	20% E'	20% C/E	20% C/E % Change
C_{121}	Timeliness	.5112	195.60	2.22	.5237	190.94	4.53
C_{122}	Accuracy	.5095	196.246	1.88	.5191	192.63	3.685
C_{123}	Reliability	.5099	196.093	1.953	.5199	192.34	3.831
C_{124}	Content	.5086	196.627	1.686	.5171	193.366	3.32
C_{11}	Need	.5198	192.365	3.82	.5397	185.3	7.35
C_{21}	Image	.5126	195.09	2.453	.5251	190.42	4.789
C_{22}	Data Base	.5150	194.17	2.912	.5300	188.68	5.66
C_3	Operating Cost	.5184	192.88	3.588	.5369	186.26	6.871
C_4	Success	.5353	186.79	6.606	.5707	175.21	12.393

intended importance relationships. This first type of analysis is of the model itself and does not directly relate to the specific candidate applications. It should be used primarily in adjusting the criterion weightings in future iterations of the evaluation process. In the review of the results in Table 3, no weighting/inconsistencies were noted by the evaluation committee.

A second type of sensitivity analysis performed on the results, tests whether the priority relationships among the applications are significant. This analysis was accomplished by determining what magnitude of changes in each criterion's average score would be necessary to reverse each particular portion of the priority ranking. These rank-reversing score changes are presented in Table 4 and are related to the standard deviation of scores among individual evaluators. The probability of ranking changes due to reconsideration of certain criteria by the evaluators is assumed to be a function of the scoring variations and hence can be subjectively assessed from Table 4.

Study of Table 4 indicates that the applications' rankings all seem significant with the exception of the priority of alternative D, pharmacy over C, radiology. For the D, C ranking, it is seen that a change in the need criterion, C_{11}, equal to a fourth of one standard deviation of the individual scores, would reverse the rankings. Since such a small change could be encountered by a relatively minor change in the selection of evaluators or by the inexactness of the subjective scoring, the difference between the cost/effectiveness values of pharmacy and radiology is not too significant and their order of implementation is of relatively little consequence.

Table 4. Ranking Significance Analysis.

Applications Whose Relative Rankings Are to be Reversed	% Change Needed	Change in Score of Each Criterion Needed to Reverse Ranking Order — CRITERION C_{121}	C_{122}	C_{123}	C_{124}	C_{11}	C_{21}	C_{22}	C_{3}	C_{4}
1. A, B										
a. Reduction of A's score	21.3	.522	.621	.596	.693	.215	.541	.456	.369	.153
% standard deviation		3.56	5.12	3.51	2.88	.82	2.86	1.84	-	1.70
b. Increase of B's score	17.6	.355	.423	.406	.472	.195	.607	.509	.414	.122
% standard deviation		2.22	3.49	3.35	1.90	1.13	4.34	1.87	-	.766
2. B, D*										
a. Reduction of B	69.1					.536				.336
% standard deviation						1.94			-	2.11
b. Increase of D	41.3					.375				.255
% standard deviation						1.44			-	2.31
3. C, D										
a. Increase of C	3.99	.089	.106	.102	.119	.038	.107	.090	.073	.029
% standard deviation		.34	.711	.681	.515	.212	.444	.367	-	.262
b. Reduction of D	4.16	.107	.127	.122	.142	.052	.120	.100	.082	.035
% Standard Dev.		1.00	.605	.502	.97	.199	.706	.369	-	.316

*Omitted values are insignificant by inspection

Although the selection between the two mutually exclusive laboratory applications studied must be based upon the incremental analysis described earlier, a reversal of the original rankings would automatically lead to the selection of the more costly application regardless of the MAR. For this reason it is important to ascertain if the ratios of the two laboratory alternatives are significantly different. Table 4 provides some insights into this significance by indicating that no criterion change of less than 0.75 σ would reverse the ranking. Because such a large change is unlikely, the differences in cost/effectiveness between A and B appear significant. However, because of the marginal possibility of a .75 σ change occurring, and to demonstrate the procedures of iterative scoring for applications with less significant differences, further analysis of the most critical factors was undertaken and is discussed later in this chapter.

The difference between applications B, Laboratory #2, and D, Pharmacy, is highly significant requiring a 1.44 σ change in the most critical criterion score to reverse the priority order.

Another aspect of scoring model design having an impact on the evaluation results is the estimation of the scoring functions. In the trial application these scoring function distributions were assumed normal with means, $\mu = 0.5$ and $\sigma = 0.1938$. Review of Figure 10 indicates that the great majority of average scores for the applications substantially exceeded 0.50. For this reason a sensitivity analysis was performed to determine the effect that re-estimated scoring distributions would have on the results. Scores for each criterion were assumed to have a mean equal to the average of all scores assigned to the sample applications for that criterion. The normality assumption was maintained and the standard deviation of each distribution was chosen so that 99.5 percent of all scores would be less than 1.0. The basic score averages were then converted to standardized, N(0.5, 0.1938), scores using the re-estimated distribution parameters. Table 5 shows a comparison of the raw average scores and the adjusted or standardized scores after conversion.

The adjusted scores were then used in the model calculations to obtain effectiveness ratings and cost/effectiveness rankings for each alternative. As shown in Table 6, these results do not differ from the original priority rankings for the four applications.

Further, in Figure 11, it is illustrated that although the re-estimation of the distribution means significantly shifts the effectiveness scores of all applications, the relative differences in scores between applications are affected very little. It should be noted, however, that even these small changes could cause a reversal of priorities between applications whose initial cost/effectiveness ratings were relatively close. For this reason, re-estimation of scoring distributions based upon initial scores assigned should be included in the sensitivity analysis of the scoring model results.

In addition to the sensitivity analyses discussed previously, a number of other interesting observations were noted regarding the methodology demonstration. To determine if significant differences in the basic evaluations of each evaluator existed, the effectiveness ratings and cost/effectiveness rankings were calculated using the

Table 5. A Comparison of Original Scores and Scores Adjusted Using Re-estimated Scoring Distributions.

Criterion	$\bar{x}$	σ	Lab #1		Lab #2		X-Ray		Pharmacy	
			s	s'	s	s'	s	s'	s	s'
C_{121}	.671	.1285	.675	.506	.833	.744	.700	.544	.475	.204
C_{122}	.750	.0977	.783	.565	.783	.565	.733	.466	.700	.401
C_{123}	.700	.1172	.667	.445	.783	.637	.733	.555	.617	.363
C_{124}	.610	.1523	.542	.414	.550	.424	.625	.519	.725	.646
C_{11}	.677	.1262	.600	.382	.825	.727	.667	.485	.617	.408
C_{21}	.685	.1230	.650	.445	.808	.694	.753	.607	.533	.260
C_{22}	.638	.1414	.680	.558	.640	.503	.600	.448	.630	.489
C_4	.704	.1156	.717	.522	.692	.480	.642	.396	.767	.606

s = original average scores

$\bar{x}$ = mean of sample scores

s' = standardized scores based on sample mean

Table 6. Cost/Effectiveness Calculations Using Re-estimated Scoring Distributions.

	Candidate Applications			
Development Cost	Laboratory #1	Laboratory #2	Radiology	Pharmacy
	$83,000	$128,000	$152,000	$186,000
Effectiveness	.465	.694	.351	.498
Cost/Effectiveness	178.5	184.4	443.0	373.0
Ranking	1	2	4	3

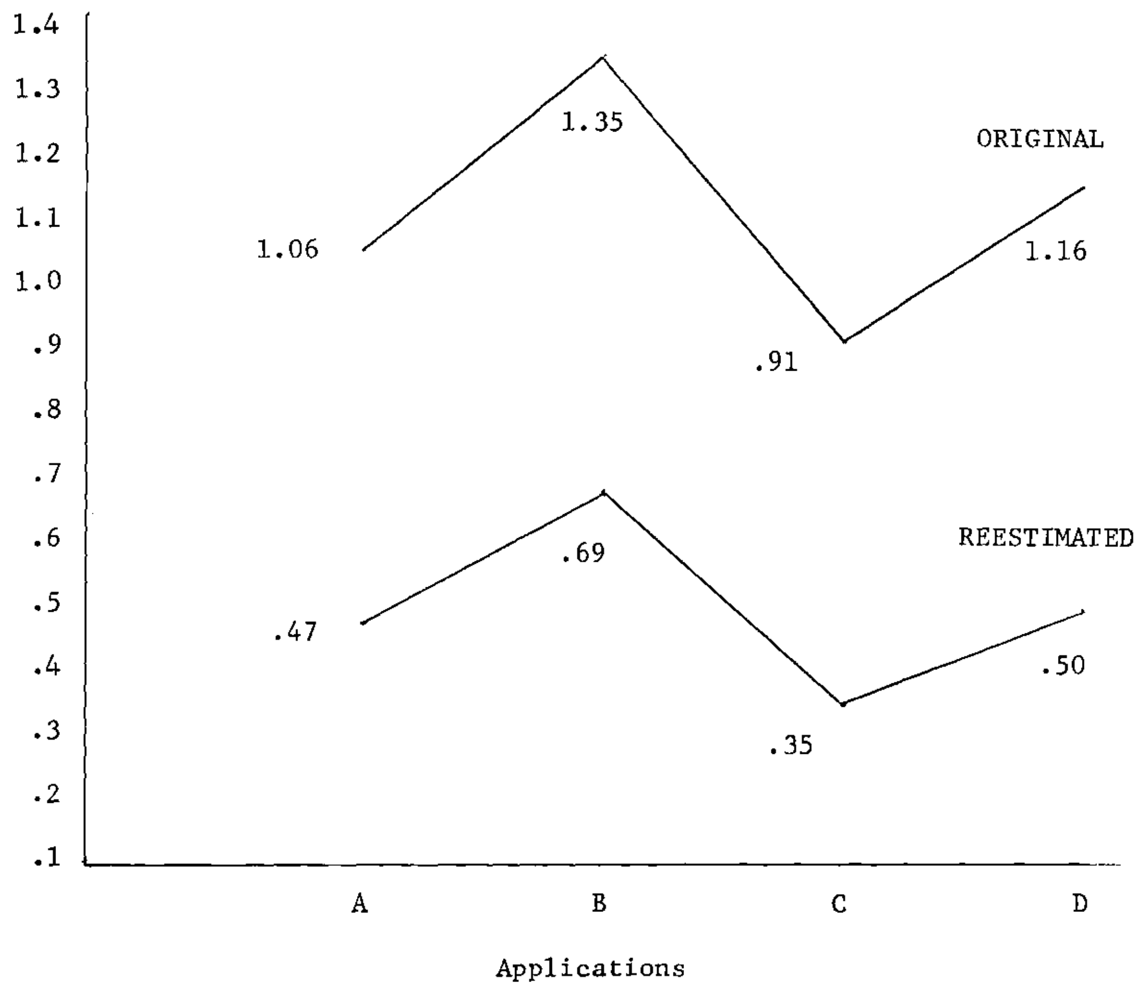

Figure 11. Effectiveness Values Using Original and Re-estimated Scoring Distributions.

scores of each participant. The results shown in Table 7 reveal that all individual rankings agreed with those of the average except for the reversal of the priorities for the pharmacy and radiology applications for two evaluators. These results are highly consistent with the previously stated finding that the implementation order between the pharmacy and radiology applications was of little significance.

Another aspect of the scoring model considered in the analysis regards the role of the chance of success criterion. As can be seen in Table 3, the scores of the chance of success criterion carry considerable weight. In addition, these scores are highly subjective and difficult to evaluate. To test the impact of this criterion on the results of the scoring model, the priority rankings were recalculated without considering the success factor. The resulting rankings, as shown in Table 8 and Figure 12, vary from the original results only in the reversal of the radiology and pharmacy applications. This relative insensitivity to the chance of success criterion is caused by the small variance among the average chance of success scores among the four applications as shown in Figure 13.

If the changes in the rankings due to the elimination of the chance of success criterion had been more significant, the evaluation committee would have had to look more closely at both the weighting and scoring of it.

Reevaluation of Critical Criteria

As discussed previously, and shown in Table 4, the sensitivity analysis indicated that a .766 σ change in the score of the chance of

Table 7. Cost/Effectiveness Calculations Based Upon the Scores from Each Evaluator.

		Candidate Applications		
	Laboratory #1	Laboratory #2	Radiology	Pharmacy
Development Costs	$83,000	$128,000	$152,000	$186,000
Evaluator #1				
#1 Effectiveness	.507	.501	.479	.605
Cost/Effectiveness	163.7	255.5	317.3	307.0
Ranking	1	2	4	3
#2 Effectiveness	.933	1.384	.923	.958
Cost/Effectiveness	89.0	92.3	164.7	194.2
Ranking	1	2	3	4
#3 Effectiveness	.688	.840	.773	1.027
Cost/Effectiveness	120.6	152.4	196.6	181.1
Ranking	1	2	4	3
#4 Effectiveness	1.290	1.833	.807	1.325
Cost/Effectiveness	64.34	69.83	188.00	181.1
Ranking	1	2	4	3
#5 Effectiveness	1.416	1.260	.615	.988
Cost/Effectiveness	58.6	101.6	247.0	188.3
Ranking	1	2	4	3
#6 Effectiveness	1.490	1.998	1.637	1.850
Cost/Effectiveness	55.7	64.1	92.9	100.5
Ranking	1	2	3	4

Table 8. A Comparison of Scoring Model Results with and without the Chance of Success Criterion.

	Candidate Applications			
	Laboratory #1	Laboratory #2	X-Ray	Pharmacy
A. Original Results				
Effectiveness	1.059	1.346	.907	1.156
Cost/Effectiveness	78.4	95.1	167.6	160.9
Ranking	1	2	4	3
B. Without Success Criterion				
Effectiveness	.900	1.226	.838	.931
Cost/Effectiveness	92.2	104.4	181.4	199.8
Ranking	1	2	3	4

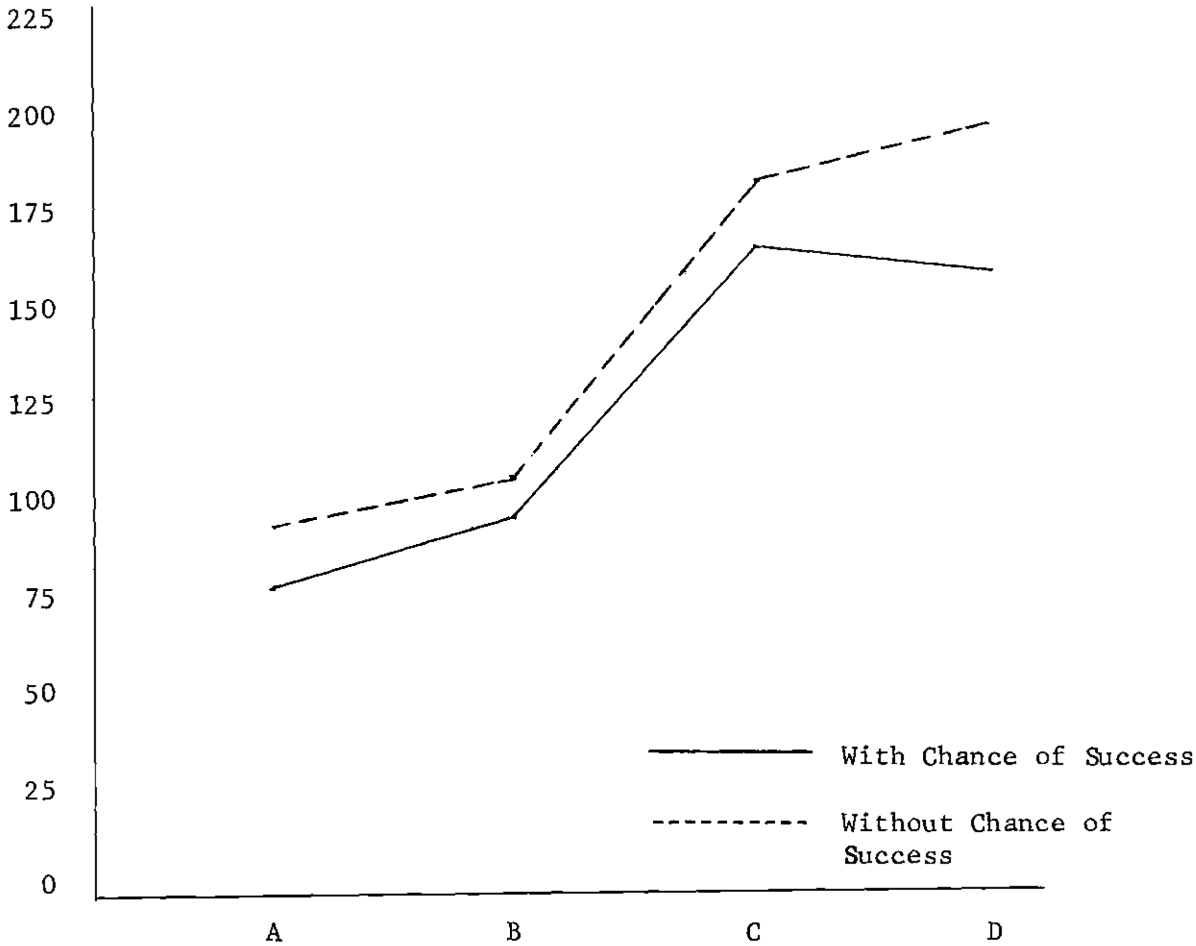

Figure 12. Cost/Effectiveness Ratios with and without Chance of Success Criterion.

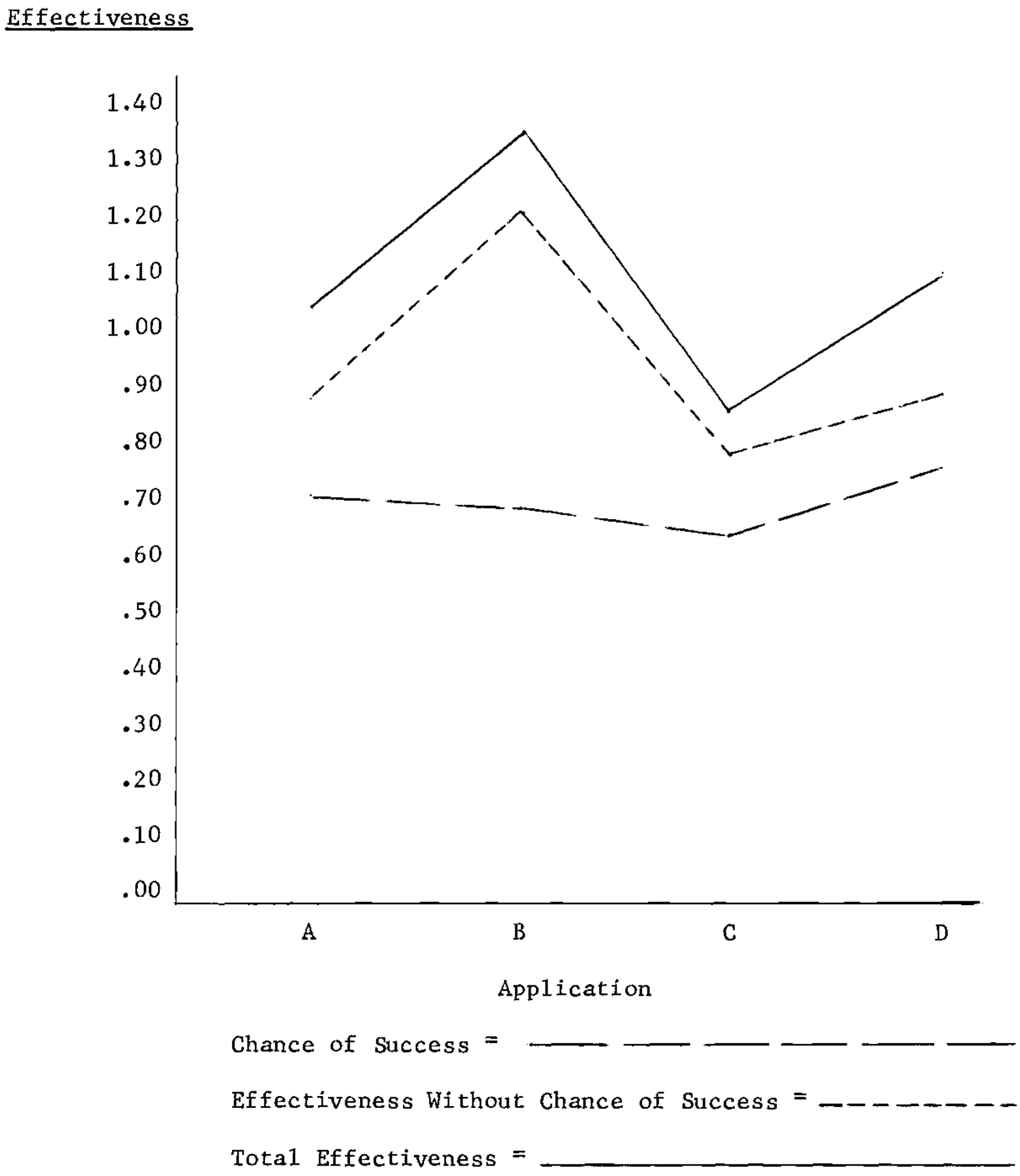

Figure 13. Impact of Chance of Success Criterion.

success criterion of the Laboratory #2 application, or a .820 σ change in the score of the need for improvement criterion for the Laboratory #1 application would reverse their priority rankings. Here, the σ's refer to the standard deviations calculated for the scores assigned each application for each criterion by the six evaluators. Although such a large change seemed unlikely, it was decided to pursue the evaluation of these two criterion further. Therefore, each evaluator was given the list of the original scores received for these two criteria and asked to review his own scores in relation to the average scores received. Further, each evaluator was asked to rescore any of his original scores if his assessment had changed after the review and to give an explanation of any of his scores which were significantly different from those of the other evaluators. The results of the scoring iteration are presented and compared with the original average scores in Table 9 and further illustrated in Figures 14 and 15. Also shown are the original and recalculated standard deviations among evaluators for each score.

These results were then used in calculating a new set of cost/effectiveness ratings and priority rankings for the applications. Table 10 and Figure 16 compare these rankings with those obtained from the original scores.

Although Table 10 shows a reversal in the ranks of the Pharmacy and Radiology Applications, changes in the cost/effectiveness ratings of the laboratory applications are relatively small. Further, these rating changes in the laboratory alternatives tend to make the differences between them even more significant. This significance is increased

Table 9. Results of Scoring Iteration of Critical Criteria.

Criterion	Application							
	Laboratory #1		Laboratory #2		Radiology		Pharmacy	
	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ	$\overline{X}$	σ
Need for Improvement								
Original	.60	.261	.83	.173	.67	.180	.62	.261
Revised	.58	.105	.82	.120	.68	.113	.55	.190
Chance of Success								
Original	.72	.090	.69	.159	.64	.184	.77	.111
Revised	.75	.114	.68	.133	.61	.183	.72	.060

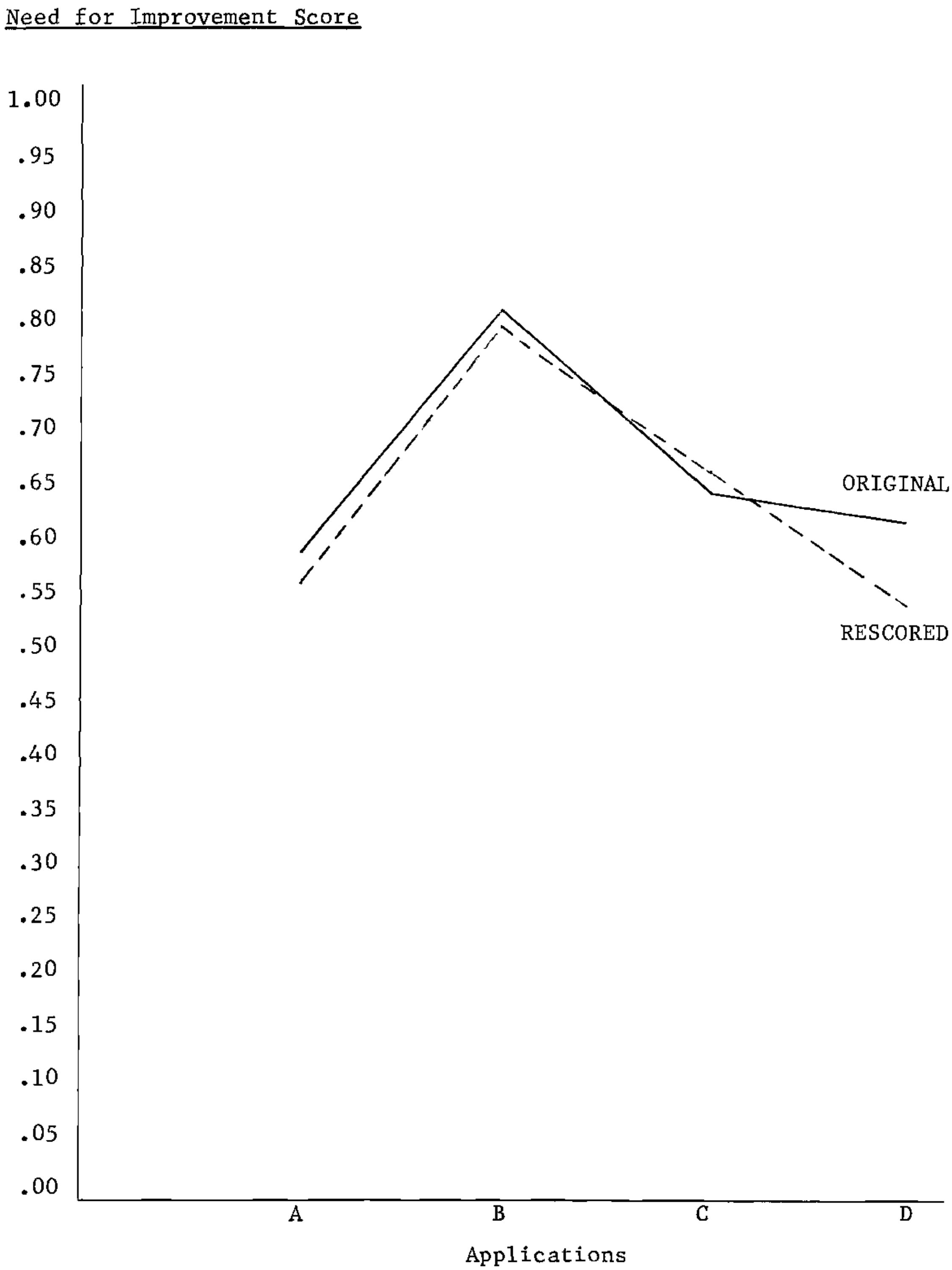

Figure 14. Reevaluation of Need for Improvement Criterion.

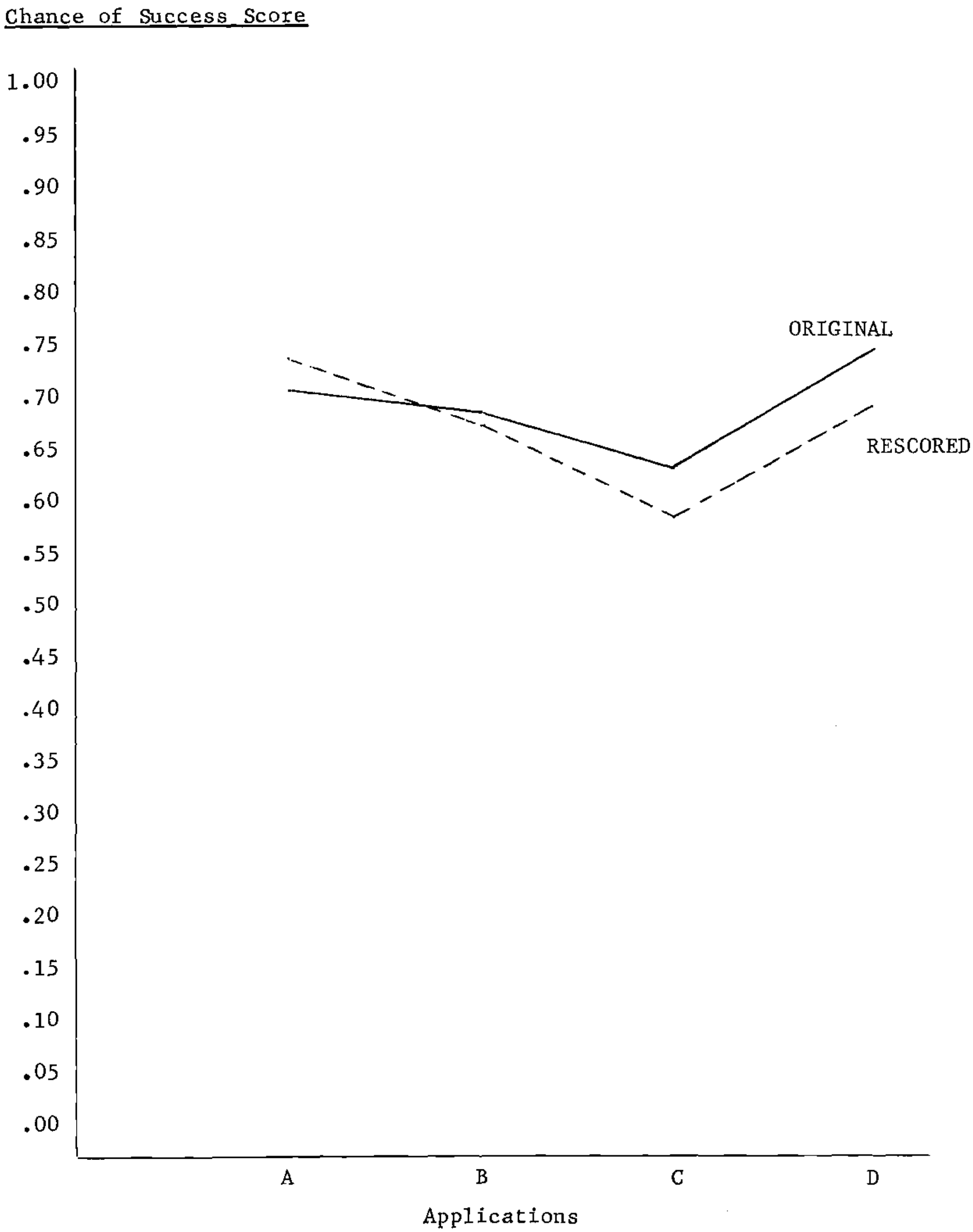

Figure 15. Reevaluation of Chance of Success Criterion.

Table 10. Cost/Effectiveness Ratings and Priority Rankings From Scoring Iteration.

	Candidate Applications			
	Laboratory #1	Laboratory #2	Radiology	Pharmacy
Development Cost	$83,000	$128,000	$152,000	$186,000
Original Scores				
Effectiveness	1.059	1.346	.907	1.156
Cost/Effectiveness	78.4	95.1	167.6	160.9
Ranking	1	2	4	3
Revised Scores				
Effectiveness	1.082	1.321	.880	1.041
Cost/Effectiveness	76.7	96.9	172.7	178.7
Ranking	1	2	3	4

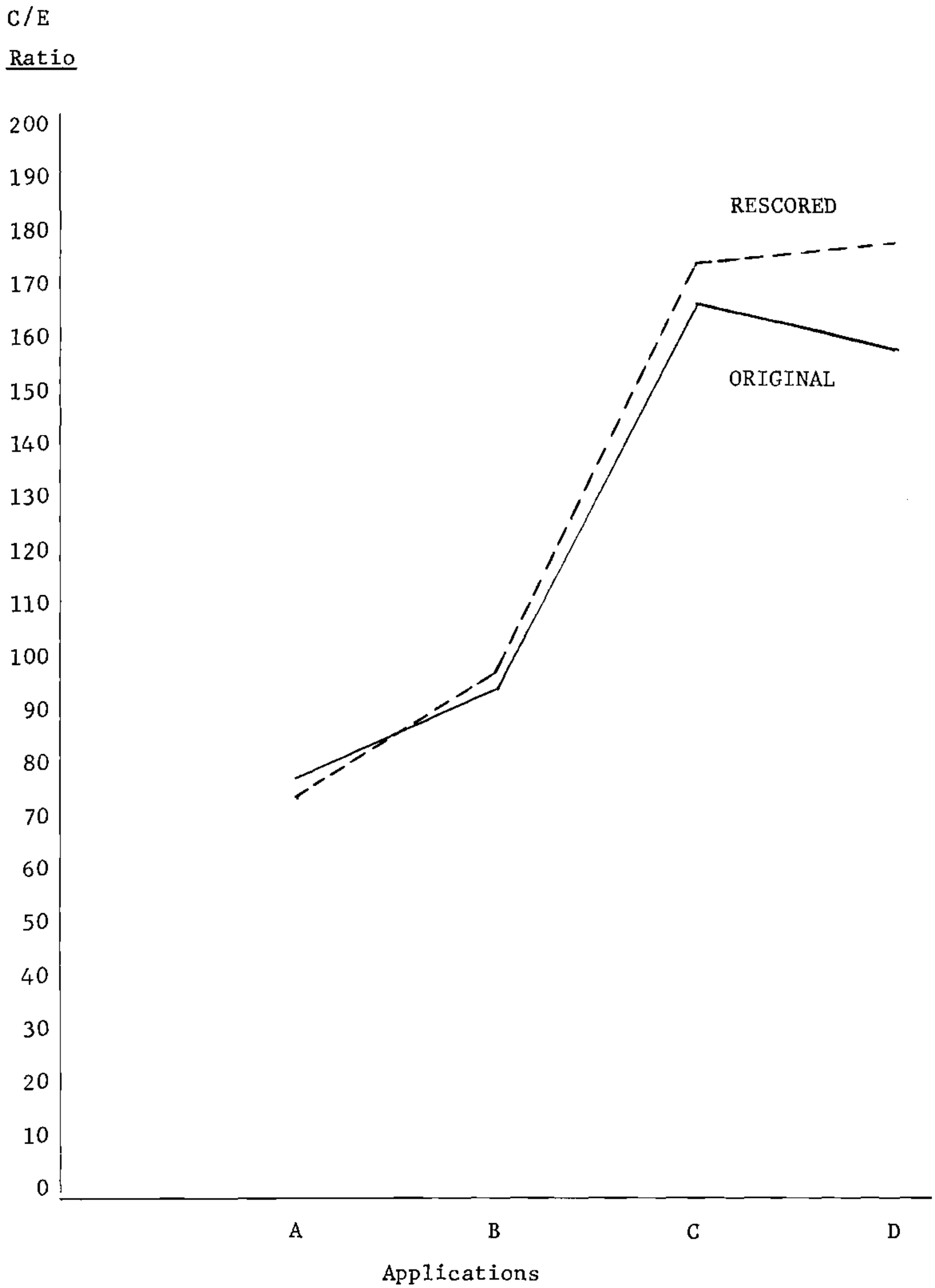

Figure 16. Cost/Effectiveness Ratings from Scoring Iteration.

further by the recalculated standard deviations for the two critical criterion-application combinations. For example, if the recalculated standard deviations, as seen in Table 9, are substituted for those of the need for improvement and chance of success criteria in Table 4, the minimum required change to reverse the laboratory rankings would be a .92 σ change in the chance of success score for the Laboratory #2 alternative. Since the change in that average score due to the scoring iteration was only .075 σ, it is highly unlikely that further iterative scoring would reverse the rankings.

The discussion presented above was provided primarily to illustrate how the significance of a rating difference between two independent applications could be better determined through iterative scoring by the evaluators. However, since in the methodology demonstration, the two laboratory applications are mutually exclusive, a reanalysis of their incremental investment proposal is called for.

This is accomplished by using the newly calculated effectiveness ratings to revise Table 2 as is shown in Table 11.

Since the incremental cost/effectiveness rating of 188.5 is now greater than the ratios for the Pharmacy and Radiology applications (178.7 and 172.7), it could now exceed the maximum acceptable ratio and the selection of the Laboratory #2 application is no longer automatic. Instead, acceptability of the incremental ratio should be subjectively considered by the planning committee and compared with other known acceptable cost/effectiveness ratios. Only if 188.5 is considered below the maximum acceptable ratio should the more costly application be chosen. Because of the proximity of the incremental ratio to that

Table 11. Revised Incremental Analysis of Laboratory Applications.

Application	Development Cost	Effectiveness	C/E Ratio
A. Laboratory #1	$83,000	1.082	76.7
B. Laboratory #2	$128,000	1.321	96.9
B-A. Incremental	$45,000	.239	188.5

of the pharmacy application, the incremental investment was assumed acceptable for the purposes of demonstration, and the Laboratory #2 application was selected.

Determination of the Implementation Schedule

Because the primary purpose of the demonstration was to better explain the guidelines and procedures directly involved in the design and application of an HIS scoring model, and since the specific HIS environment and candidate applications considered in the demonstration were not taken from a specific hospital or institution, the development of a final implementation schedule for the four applications was not included in the demonstration. However, the general considerations involved in adjusting the scoring model-produced implementation schedule to obtain a recommended order of implementation were discussed by the MCG planning committee. A summary discussion of these considerations is presented below.

In general, the HIS planning committee must analyze all aspects of the evaluation which were not considered in the scoring model before recommending an implementation schedule. To accomplish this, all underlying assumptions of the methodology should be reviewed. The assumption of independence among HIS applications was initially justified for use in the model by the consideration of a large fixed overhead for the planning horizon. In practice, however, the ease of the development and installation of this software and equipment is related to the implementation schedule. In short, there is a preferred order of implementation from the systems development viewpoint. Since this preferred order is not directly included in the scoring model evaluation the model results must be reviewed in light of the technical development priorities to determine if schedule adjustments are warranted. This should be determined by both the differences in cost/effectiveness rankings between applications and the cost savings attainable by the preferred technical order of implementation.

Another consideration to be made by the planning committee involves nonsequential implementation. The nature of HIS development appears to demand some degree of overlap in application implementation. Such overlaps should be planned and appropriate adjustments should be made in the implementation schedule. If substantial overlap or simultaneous development of several applications appears desirable, the relative effects on the development costs and times of completion for each application involved should be reviewed. Such changes might warrant adjustments in the priorities.

In addition, the planning committee should consider the hospital's need for quick returns or other timing aspects not incorporated in the scoring model. A discussion of considerations regarding the time-cost proportionality of application development and the time value of benefits is presented in Chapter IV.

Finally, the committee should review the implementation schedule in light of possible changes in the overall HIS funding level. Contingency development and implementation plans should be determined within the range of possible budget allocations.

The above mentioned considerations which the planning committee should make in recommending an implementation schedule are not highly structured and are dependent upon each specific planning environment. As discussed in the following chapter, it appears that the insights gained by the evaluators in the more structured scoring model portion of the evaluation should better enable the proper analysis of these other considerations.

CHAPTER VI

EVALUATION OF THE METHODOLOGY'S APPLICABILITY

After the results of the scoring model and the sensitivity analysis were presented to the planning committee, the evaluators were asked to discuss the weaknesses, benefits and general applicability of the methodology's scoring model approach to HIS priority setting. The assessments brought out in the discussion and further comments and responses solicited from the evaluators in a short questionnaire are summarized in this chapter.

Need for HIS Priority Setting

The evaluators were first asked to assess the need for determining HIS priorities for a hospital planning to implement a real-time information system. The committee's almost unanimous response was that the need is "great" rather than "moderate," "very little," or "none," as indicated by the summary of responses to the questionnaire included in Appendix D. This assessment of great need is consistent with and supported by similar appraisals reported in the literature (17,51) and discussed in Chapter II.

The primary reasons for the need for HIS priority setting were determined by the MCG committee to involve a combination of considerations regarding the technical development sequence of implementation, the political rivalries among various areas of the hospital, and the desire to maximize benefits received for dollars invested. Although no clear consensus was given regarding the relative importance of the three factors, it was indicated in the discussion that the technical and political aspects were the most overt while the consideration of the maximization of benefits, even though intuitively more appealing, was more obscure and therefore less demanding.

Weaknesses of the Scoring Model

Both through the discussions and the questionnaire, the evaluators were invited to comment regarding the weaknesses of the scoring model used in the demonstration and their implications for the general use of the scoring model approach to HIS priority setting. The evaluators' responses indicated that most of the simplifying assumptions made in developing both the general methodology and the specific scoring model used in the demonstration may have had detrimental effects on the scoring model results. The scoring model's inability to consider the interdependencies of certain applications and its restriction regarding the fixed nature of the overhead system were considered to introduce significant inaccuracies in the scoring model results. In addition, the assumption regarding the purely sequential method of implementation was viewed as unrealistic. Other considerations such as those discussed in Chapter IV regarding the time value of benefits and the fluctuation of criterion importance weightings among applications were also questioned in regard to the possible bias that they might introduce into the numerical results.

Although the above mentioned weaknesses in the scoring model's numerical results were clearly identified, the committee's general comments indicated that the methodology's true usefulness seemed not to be affected significantly by these inadequacies. In general, the committee felt that the joint participation of the planning team members in the criterion selection and weighting process and in the systematic analysis of each HIS application, as required by the scoring model development and application, offered and methodology's greatest benefits. Accordingly, members of the MCG planning team felt that once this process had been established, and once the HIS planning committee had determined a structure for the evaluation based on its selected criteria, the committee would be able to adjust the scoring model's initial rankings to appropriately compensate for all significant aspects not considered in the model. For this reason, the committee was less concerned with refinement of the scoring model than with the proper expression of the limitations of the model and its numerical results so that all other considerations could be included in the evaluation process and contribute to the development of the recommended implementation schedule.

Scoring Model Applicability

To provide a better focus on the applicability of the overall scoring model approach, each evaluator was asked if he would recommend its use in setting HIS priorities. Five of the six evaluators responded that they would recommend it. Again, the primary reason indicated for these responses involved the benefits to be obtained from the evaluation "process" rather than from the numerical results of the scoring model. Although the discussions indicated that refinements in criterion definitions, weightings, and scoring functions would be made with iterative use of the scoring model throughout the HIS planning, one evaluator conjectured that after several iterations, the benefits from the evaluation structure or "process" might be fully gained, allowing the HIS committee to determine priority rankings without the need for formal score assignments for each criterion.

In spite of their recommendations for its use, the MCG planning committee members indicated some reservations regarding the applicability of the scoring model approach to determining HIS priorities. In general, the evaluators felt that although the demonstration had given them adequate knowledge of the procedures involved in developing an HIS scoring model, additional experimental use of the methodology's approach on a continuous basis in an actual hospital environment and further development of the other aspects of the methodology would better indicate its applicability.

In summary, the MCG planning committee felt that the HIS priority problem was indeed significant and that the scoring model approach appears to be useful in its solution because of the insights which its evaluation process brings to the participants. However, since the worth of these sharpened insights in continued HIS planning could not be properly evaluated in the scoring model demonstration, the committee felt that adequate appraisal of the methodology's overall applicability could not be made until further trial applications could be conducted and evaluated in actual hospital environments over a continuous HIS planning period.

In addition, the planning committee members indicated that the approach appears to be applicable to many other health care planning decisions. Again, the benefits of the insights to be gained from the "process" of evaluation were stressed while some reservations were indicated regarding full endorsement until additional trials in actual hospital planning situations could be performed and evaluated.

Cost of Demonstration

In addition to the benefits to be gained from the scoring model approach, the cost of its use is also a determining factor in its general applicability. These costs will probably include the salary of a full-time coordinator as well as the value of the time each participant contributes to the planning effort.

The coordinator could do such things as preparing the agenda for each planning meeting, providing the technical assistance needed for designing the scoring model, and consolidating all quantitative data from analyses of information requirements, potential application performances, and expected application costs. He also tabulates the resulting evaluation scores, performs the sensitivity analysis, and reports the results back to the evaluation team.

In the application demonstration, the MCG planning team contributed nearly 60 man-hours during the six planning sessions required. Using an assumed average total cost of $12 per hour for the participants, the cost of their time is calculated to be $720 for the demonstration. In addition, the cost of a full-time coordinator for the three-month period of active involvement is estimated to be approximately $5000. Other costs for typing, copying and miscellaneous supplies related to the priority planning activities would bring the estimated total cost of the demonstration to about $6,000.

Although the participants in the use of an HIS scoring model in a real-world situation would have to review the information requirements and application descriptions in greater detail than that needed for the demonstration, because their first-hand knowledge of the situation would provide a better background to relate such analyses to, the time required of them specifically for the priority setting process should be comparable to that given in the demonstration. Therefore, the $6,000 would appear to be a reasonable estimate of the costs encountered in using the scoring model and cost/effectiveness analysis portions of the methodology. Because the information gathering portions of the methodology should also be required in the cost justification phases of HIS planning, and since they were not applied in the demonstration, additional research would be required to determine the additional costs they create.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this research was to develop a general methodology for determining implementation priorities among candidate applications to a real-time, patient-oriented hospital information system. In this regard guidelines for developing customized scoring models to be used in determining such priorities in individual hospitals were established, described, and demonstrated within a general framework of the overall methodology.

Several specific objectives were outlined in Chapter III. The next section of this chapter first presents conclusions related to each objective. Then, general conclusions are drawn. In the last section of the chapter, recommendations are offered regarding possible improvements to the methodology and further demonstration of its applicability.

Conclusions

The first objective of this research was to develop a general planning approach to setting HIS priorities. The approach developed and described in Chapter IV suggests a systematic method for establishing information requirements, identifying and screening potential HIS applications, and determining their implementation priorities using cost/effectiveness analysis. The approach is based upon the development of a customized scoring model for each individual hospital to use in determining its own HIS priorities. In addition to determining priorities among independent applications, the approach includes procedures for selecting among mutually exclusive alternatives using incremental cost/effectiveness analysis.

In developing the general approach, primary emphasis was placed on establishing guidelines and procedures for the development of customized HIS scoring models, the second objective of the study. Each critical aspect of HIS scoring model design was discussed and methods for prohibiting unintended bias in the scoring model results were presented. Such methods include the use of both additive and multiplicative relationships among selected criteria and the corresponding mathematical calculations necessary to maintain the consistency of the criterion importance weightings. In addition, guidelines were presented regarding the selection of interdependent criteria, the method of criterion weighting, and the design of criterion scoring functions.

In accomplishing the third objective, the use of these guidelines and procedures was demonstrated in the development of a scoring model for a mock hospital. Members of an HIS planning team from the Medical College of Georgia participated in the development and use of this scoring model for determining the implementation priorities for four constructed HIS applications. As discussed in Chapter VI this trial application provided to the MCG team of experts an adequate demonstration of the guidelines and procedures required for scoring model design.

The fourth study objective, that of evaluating the applicability of the methodology, was only partially accomplished. The limitations of the numerical results of such scoring models were determined not to compromise the applicability of the approach. However, since the potential enhancement of the decision makers' insights through their participation in the scoring model evaluation process was identified as the primary justifying benefit of the approach, additional use of the methodology in actual HIS planning situations to determine the realization of these benefits was found to be required before the methodology's true applicability could be determined.

It should be noted that although the numerical results produced by the scoring model are not suitable for direct conversion into the implementation schedule, they do provide the basis for such a schedule, requiring adjustments for only the specific limitations of the scoring model. For this reason, the importance of the guidelines for eliminating unintended bias in the scoring model design remains significant.

In accomplishing the final objective, recommendations regarding additional research needed to further improve the methodology and to demonstrate its applicability are presented later in this chapter.

In general the evaluation approach resulting from this research provides sound guidelines for the development of an HIS scoring model as well as the general procedures for its use in evaluating candidate applications and determining their implementation priorities. Although the numerical results of such a scoring model and their corresponding priority rankings do not appear completely adequate for schedule determination because of the model's apparent inability to consider all aspects of the real-world environment, these results do provide valuable inputs to the question of how best to order the implementation of HIS applications. In addition, the process of systematically and consistently analyzing all candidate applications using well defined criteria within an overall evaluation structure, as required by the methodology's scoring model approach, appears to sharpen the insights of the decision makers and allows them to perform better the final determination of the implementation schedule.

The specific guidelines for scoring model design as well as the general approach were demonstrated by their application in the mock HIS planning situation to clarify their use in determining HIS priorities. Moreover, the MCG planning committee indicated that such demonstration was sufficient for them to recommend the use of the approach for hospitals involved in HIS development. It is therefore concluded that the fundamental aim of this research has been achieved.

Recommended Areas for Further Research

The final objective of this study was the identification of promising and important areas of the HIS priority planning process which are appropriate for additional research. It is apparent that many of the assumptions incorporated in the general methodology to allow or simplify the use of the scoring model approach detrimentally affect the validity of the model's numerical results. Although these deficiencies can be alleviated to some degree through subjective considerations by the evaluation committee and corresponding adjustments to the model results, the necessity for such subjective treatment weakens the methodology as an objective evaluation tool. The development of methods to permit more realistic assumptions would therefore improve the methodology. In the interest of promoting additional research related to HIS priority determination, several suggestions for developing such methods are presented below:

1. Develop a method for analytically considering the interdependencies among candidate HIS applications. Development cost dependencies might be best addressed using a suboptimizing, iterative approach in which the highest ranking application would be selected and added to the overhead system allowing the development costs and priority rankings of all remaining applications to be reevaluated.
2. Establish an analytical method for including considerations of development cost-development time disproportionalities and the time value of benefits more objectively in the methodology.
3. Develop methods which would allow consideration of simultaneous implementation of several applications to be incorporated within the methodology structure.
4. Establish methods to relate the determination of HIS priorities to the overall availability of HIS funding during the planning horizon.

In addition to improvements in the assumptions used in the methodology, several additional areas for research can be listed. Accordingly, each of the following topics appears to be fertile ground for future investigation:

1. Develop consistent and comprehensive methods for estimating the development and operating costs of candidate HIS applications.

2. Determine the feasibility of establishing a maximum acceptable cost/effectiveness ratio (MAR) for HIS applications.
3. Investigate the possibility of adjusting criterion importance weightings to account for differences in the characteristics of each information subsystem while maintaining a consistent evaluation structure.
4. Identify the actual scoring distributions of certain criteria for a large number of candidate applications and determine the affect of the substitution of simpler distribution approximations on the scoring model results.
5. Investigate the role of the chance of success criterion in HIS priority planning and develop methods for its appropriate consideration within the scoring model.

A final area appropriate for additional research involves a better determination of the methodology's applicability to HIS priority planning. Demonstration and evaluation of the design and use of scoring models over an extended period of HIS planning and development in a real-world environment would be most helpful in this regard. Such a study should attempt to monitor the development of planning insights for each individual participating in the methodology application and to analyze the degree to which other potential benefits of the approach are realized.

APPENDICES

APPENDIX A

DESCRIPTION OF INFORMATION SUBSYSTEMS

Clinical Laboratory Subsystem--Present

I. Scope: Provides clinical laboratory services to both inpatients and outpatients.

II. Workload: 412,500 Inpatient Tests/year
108,000 Outpatient Tests/year
520,500 Total tests per year

25 Tests/Admission
2 Tests/Outpatient visit

Workload Breakdown (by number of unweighted tests)

HISTOPATHOLOGY	2.8%	HEMATOLOGY	16.8%
CYTOLOGY	4.0%	SEROLOGY	5.4%
CHEMISTRY	44.9%	BLOOD BANK	1.9%
URINALYSIS	4.9%	MICROBIOLOGY	16.4%
PARASITOLOGY	3.0%		100.0%

III. Current Procedure

A. Inpatient

1. Three part requisition handwritten from doctor's orders.
2. Requisition picked up by phlebotomist who collects specimens on a routine schedule.
3. Receipt of specimen and control number assignment in laboratory.
4. Workbooks prepared for blood chemistry.
5. Tests performed and reported on requisition or workbook.
6. Results batched and dispatched to nursing area.
7. Counts taken for daily and monthly test totals.

B. Outpatient

1. Physician writes requisition.
2. Patient carries requisition to laboratory and waits.
3. Specimen collected and patient released.
4. Rest of procedure is identical to that for inpatients except the results are batched and sent to medical

records for entry into patient chart.

IV. Performance Levels--Current

A. Cycle Time (specimen collection to report availability[1])
% of tests available within cycle time

Cycle Time	INPATIENTS Routine	INPATIENTS Stat	OUTPATIENTS Routine	OUTPATIENTS Stat
4 hours	40%	90%	5%	60%
12 hours	70%	95%	30%	--
24 hours	90%	99%	50%	90%
48 hours	?	-	80%	-
1 week	99%	-	85%	-

[1] report availability means either inpatient chart or communicated to physician.

B. Accuracy

1. Requisition errors cause 8% of tests to be rerun.
2. The clerical error rate in reporting results has been estimated between 5.0% and 7.0%.

C. Reliability

1. 15% of all outpatient lab results are lost (never get to chart).
2. Inpatient reliability estimated above 95%.

V. Other Inputs:

A. Physicians in OPC outraged at laboratory inefficiencies.

B. Public image of laboratory is low due to the number of lost or incorrect tests.

C. Administration estimates that 12% of lab revenue is missed due to lost charges.

D. Constant phone calls for STAT results cause significant interruption in laboratory area.

E. Outpatient's average waiting time for specimen collection during peak period is 20 minutes.

Radiology Subsystem--Present

I. Scope: Provides diagnostic radiology services to both inpatients and outpatients.

II. Workload: 33,000 Inpatient Exams/year
16,000 Outpatient Exams/year
49,000 Total Exams/year

Centralized Radiology Facility:

3 Radiology Exam Rooms
1 Fluorscopy Room
1 Fluorscopy/Radiology Room
1 Chest Room
1 Extremities Room

III. Procedure--Present

A. Inpatient Procedure

1. Requisition handwritten, batched on nursing unit and sent to radiology registration desk.
2. Requisition logged and patient file is pulled (routine exams are not scheduled).
3. Patient arrives and waits (average inpatient waiting time--30 minutes).
4. Exam performed and patient returned to room.
5. Film developed and read by radiologist.
6. Report of findings dictated.
7. Film filed, report transcribed.
8. Report reviewed by radiologist.
9. Report sent to nursing station and entered inpatient chart.

B. Outpatient Procedure

1. Physician writes requisition.
2. Patient carries requisition to Radiology and waits.
3. Requisition logged and file is pulled.
4. Rest of procedure is identical to inpatient except that report is sent to medical record for attaching to chart.
5. STAT reports are called to the physician.
6. For extremities (broken bone determination) patient sometimes waits for reading and carries preliminary report back to physician.

IV. Performance Levels--Present

A. Cycle Time (patient arrival, to report availability)
% of reports available within cycle time

	Inpatient		Outpatient	
Cycle Time	Routine	STAT	Routine	STAT
4 hours	-	80%	10%	80%
24 hours	90%	95%	60%	95%
48 hours	99%	99%	88%	99%
1 week	-	-	91%	-

B. Accuracy

1. Inpatient requisition errors cause 5% of exams to be rerun.
2. Relatively few errors in outpatient requisitions or in the reporting of all results.

C. Reliability

1. Inpatient reliability is very high (very few reports or films lost).
2. 8% of outpatient reports never reach patient chart.

V. Other Inputs:

1. 70% of exam load comes between 10:00 A. M. and 2:00 P. M. (primarily due to outpatients).
2. Between 10:00 A. M. and 2:00 P. M. the average waiting time before exams is 45 minutes (much delay is caused by having to pull outpatient files).
3. Physicians are outraged at outpatient exam reporting.
4. Patient's image of hospital suffers because of long waits and lost reports.
5. 10% of Radiology revenue is lost to lost charges.
6. Radiologist is constantly interrupted by calls for STAT results or missing reports.
7. Failure to complete special preparation causes long delays in 5% of inpatient exams.

Pharmacy Subsystem--Present

I. Scope: Provides all medications and pharmaceuticals to both inpatients and outpatients.

II. Workloads: Typical of 400-bed general hospital.

III. Procedure

A. Inpatient - Ward Stock and Prescription Drug Distribution

1. Physician writes medication order in chart.
2. Nurse transcribes to medix sheet.
3. Nurse makes out medication card.
4. Medication order sent to pharmacy if not in ward stock.
5. Pharmacy fills prescription and sends to nursing unit.
6. Medication cards sorted by time of administration.
7. Drugs placed with cards on medication tray.
8. Drugs checked against medix.
9. Drugs administered to patient.
10. Medix updated to show administration of drug.
11. Order made for ward stock replenishment.

B. Outpatient

1. Physician writes prescription.
2. Patient carries prescription to pharmacy and waits.
3. Prescription filled and given to patient.
4. Patient leaves.

IV. Performance Levels--Present

A. Timeliness

1. 20% of drug administrations are 30 minutes or more off of the prescribed administration time. (Disagreement between medical staff over the significance of this finding.)
2. The average response time for a STAT non-ward stock drug is 40 minutes.
3. Average outpatient waiting time during peak hour is 30 minutes.

B. Accuracy

It is thought that the multiple transacriptions and manual card sortings foster a significant number of medication errors; however, the extent or effect of these errors is not known.

C. Reliability

Approximately 1% of prescribed inpatient medications are never administered.

V. Other Inputs:

1. Approximately 40% of outpatient prescriptions are not filled by the hospital (presumably filled at other pharmacies, or not at all).
2. Drug pricing and charging errors are relatively frequent.
3. Ward stock inventory control is poor, with overstocks and understocks quite frequent.
4. Rate of stock shrinkage (% not used or chargeable to patient) is estimated at 35%.

APPENDIX B

DESCRIPTION OF CANDIDATE APPLICATIONS

Clinical Laboratory--HIS Application #1

I. Scope: Automates various aspects of requisition, control, reporting and recording of all laboratory services for inpatients. (Outpatient laboratory service remains manual.)

II. Procedures: (Inpatient Only)

1. Laboratory requisitions entered into HIS from chart and verified on CRT terminal by nurse or terminal operator.
2. One hour before collection, notice printed in nursing station or in the lab (blood chemistry).
3. Prepunched specimen identification card is printed and attached to container.
4. Specimen collected and documented at terminal before set to the lab.
5. Lab receives specimen and verifies receipt.
6. Worksheets printed with identification information (patient, test, doctor, etc.).
7. Test performed and results recorded on the worksheet, authenticated, and entered into HIS.
8. Results: (a) printed at nursing station
   (b) recorded in patient file
   (c) priced and charged for accounting

III. Expected Performance Levels

A. Cycle Time

	Inpatients	
Cycle Time	Routine	STAT
3 hours	40%	60%
4 hours	60%	90%
6 hours	90%	-
12 hours	-	99%
24 hours	99%	-

B. Accuracy

Error rates in both requisitioning and reporting are estimated to be less than 2.0.

C. Reliability

1. Lost reports are expected to be less than 1% of total (inpatients).
2. Equipment reliability is high because of dual CPU; however, terminal failures on nursing units or in lab can cause temporary delays. (Very seldom would information be lost.)

IV. Other Inputs:

A. The computer staff report no significant technical complexities regarding development of the application.

B. The medical staff is enthusiastic over the expected cycle times, but are concerned over the outpatient reporting problem.

C. The pathologist is somewhat skeptical about retraining lab personnel as terminal operators. He is also hesitant to proceed without outpatient improvements.

V. Operating Costs: (annual)

HIS System cost:	$110,000
Labor Savings:	-96,000
Other Savings:	-15,000
Total Change in Operating Cost:	- 1,000

Development Time: 6 months

Clinical Laboratory--HIS Application #2

I. Scope: Both Inpatient and Outpatient

II. Procedures:

A. Inpatient--same as Application #1

B. Outpatient

1. Physician writes order in chart.
2. Clerk enters order into HIS from chart.
   a. filed in HIS patient record
   b. printed in lab
   c. printed for order verification in chart
3. Specimen identification label printed in lab and attached to appropriate container.
4. Patient goes to specimen collection area and specimen is collected in labeled container.
5. From this point on the procedure is identical to that of the inpatient tests with the exception that the results are printed in medical records at certain periods for attaching to chart. (Note that results are still available to physician through terminal access of HIS patient record.)

III. Expected Performance Levels

A. Cycle Time

	Inpatients		Outpatients	
Cycle Time	Routine	STAT	Routine	STAT
3 hours	40%	60%	50%	60%
4 hours	60%	90%	60%	90%
6 hours	90%	-	90%	-
12 hours	-	99%	-	99%
24 hours	99%	-	99%	-

B. Accuracy

Error rates less than 2.0%

C. Reliability

1. Lost reports are expected to be reduced from 15% to 1% (Outpatient).
2. Terminal downtime less than one hour per month.

IV. Other Inputs

A. Strong support shown by physicians and outpatient staff.

B. Significant inpact of public image expected.

C. Technical development of outpatient file beyond the scheduling phase may present some difficulties.

D. Two similar applications have been implemented successfully elsewhere.

E. Retraining problems are even more significant.

V. Operating Cost (annual)

System Cost:	$172,000
Labor Savings:	-100,000
Other Savings:	-50,000

Change in
Operating Cost: $22,000

Development Time: 8 months

Radiology--HIS Application

I. Scope: (1) Automates various aspects of requisition, control, reporting, and recording of all diagnostic radiology services for both inpatients and outpatients.
(2) Provides scheduling of all inpatient exams and reminders of special preparation requirements.

II. Procedures:

A. Inpatient

1. Request of exam entered and verified on nursing terminal.
2. Requisition printed in Radiology and recorded in HIS patient file.
3. Patient's file is pulled.
4. Automatic scheduling after a review of other pending orders.
5. Special preparation requirements recorded in patient file and printed at nursing stations at appropriate times.
6. Nursing station and Radiology department notified at scheduled time.
7. Patient arrives, exam is performed and patient returns to room.
8. Films developed and read.
9. Radiologist marks coded report form and dictates special comments.
10. Report entered into HIS and printed for radiologist's verification and signature.
11. Report printed at nursing station for inclusion into chart.

B. Outpatient

1. Physician writes order in chart.
2. Clerk enters order into HIS.
   (a) filed inpatient record
   (b) printed in radiology and control number assigned
   (c) printed at outpatient terminal for order verification in chart
3. Patient film file pulled.
4. Patient arrives and waits.
5. Exam performed and patient leaves.
6. Films developed and read.
7. Rest of procedure is the same as for inpatients except that the report is printed in medical records for attachment in chart. (STAT reports are also printed at the outpatient terminal from where the request came.)

III. Expected Performance Levels

A. Cycle Time (patient arrival to report availability)
% of reports available within cycle time

	Inpatient		Outpatient	
Cycle Time	Routine	STAT	Routine	STAT
4 hours	60%	95%	60%	95%
8 hours	90%	99%	90%	99%
24 hours	99%	-	99%	-

B. Accuracy

Error rates are very low for all procedures due to verification at each step.

C. Reliability

1. Terminal downtime less than one hour per month.
2. Lost reports should not exceed .5%.

IV. Other Inputs:

1. Computer staff is somewhat apprehensive regarding the special preparation requirements and coded report forms routines.
2. Radiologists are also concerned over the coded report forms. (They do keep the option of dictating full narrative report which would then be entered.)
3. Medical staff is delighted at expected improvements in outpatient X-Ray reporting.
4. Administration estimates 90% of present lost charges would be picked up.
5. Spcial preparation requirements reminder should reduce patient stay in some cases.
6. Patient's average waiting time would be reduced to seven minutes for inpatients and 15 minutes for outpatients. (Scheduling would set bulk of inpatient exams at low outpatient load times.)

V. Operating Cost (annual)

System Cost:	$120,000
Manual Savings:	-35,000
Other Savings:	-20,000
Change in Operating Cost:	$65,000

Development Time: 10 months

Pharmacy HIS Application

I. Scope: (1) Automates various aspects of ordering, preparing, administering, and recording of all medications for inpatients.
(2) Provides automatic checks against patient allergies, drug interactions and non-normal dosages.

II. Procedures (Inpatient only)

1. Physician writes order in chart.
2. Nurse enters order in terminal.
3. Order translated and validated.
4. Order checked automatically regarding normal dosage range (if out of range, requires verification).
5. Order checked against patient file for interactions with allergies or other drugs. (If possible interactions exist, notification is printed on the nursing terminal and the order must be revalidated.)
6. Order is priced and charged to patient.
7. Floor stock checked.
8. If not in stock, order printed in pharmacy and medication label is printed.
9. Pharmacist fills order and sends to nursing station.
10. Medication schedules prepared one hour in advance of administration time.
11. Listing of conditional (PRN) orders by patient printed at the end of each shift.
12. Patient summary available for physician review.

III. Expected Performance Levels

A. Timeliness

1. Some reduction in administration time errors is expected from medication printouts by time of administration.
2. Average response time for STAT medication orders should be reduced to 30 minutes.
3. Outpatient waiting time would not change.

B. Accuracy

Validation procedures and automatic dosage checks are expected to reduce clerical errors significantly.

C. Reliability

Terminal downtime should not exceed one hour per month. Overall reliability is expected to improve with HIS application.

IV. Other Inputs

1. Drug and allergy interactions which might be caught by HIS are estimated to be less than .1% of medication orders.
2. The medical staff has shown mild approval of both the automatic checks and flaggings and the initiation of summary sheets.
3. Much tighter control of shrinkage is expected (down to 15%).
4. Better inventory control in both the ward stocks and the pharmacy would be achieved.

V. Operating Costs

System Cost:	\$86,000
Manual Savings:	-100,000
Other Savings:	-40,000

Total Change in
Operating Cost: \$56,000

Development Time: 1 year

APPENDIX C

SUMMARIES OF THE CRITERION DESCRIPTIONS, SCORING FUNCTIONS, AND PERFORMANCE LEVEL DISTRIBUTIONS USED IN THE METHODOLOGY

I. Direct Improvement Criteria

A. Need for Improvement

1. A measure of the relative need by the hospital for improvements in the activities to be performed by the HIS application.
2. Score the need for improvements in the activities or functions to be performed by each candidate application by selecting an appropriate point on the scale given below:

	SCORE
The functions are currently being performed at the optimal level ------	.0
	.1
	.2
	.3
	.4
Improvements in the functions to be covered would distinctly increase the value of those functions to the hospital ---	.5
	.6
	.7
	.8
	.9
The current performance level is not acceptable; an urgent need for improvement exists. -----	1.0

(The distribution indicates the expected probability of occurrence of candidate applications whose need scores would fall on each indicated value.)

B. Performance Output Improvements

1. Timeliness

(a) A measure of the relative improvement of the value or use of the information due to expected changes in cycle times or response times after implementation of the application. (Only the information to be handled by the application should be considered.)

(b) Score the effect on the value and use of the information of the expected changes in cycle times or response times by selecting an appropriate point on the scale given below:

	SCORE
Significantly Detrimental-----	.0
	.1
	.2
	.3
Of no Significance -----------	.4
	.5
	.6
	.7
	.8
	.9
Extremely Beneficial ---------	1.0

2. Accuracy

   (a) A measure of the relative improvement of the value or use of the information to be handled by the application due to expected changes, its accuracy or error rates.

   (b) Score the effect on the value and use of the information of the expected changes in accuracy by selecting an appropriate point on the scale given below:

	SCORE
Significantly Detrimental-----	.0
	.1
	.2
	.3
Of No Significance -----------	.4
	.5
	.6
	.7
	.8
	.9
Extremely Beneficial ---------	1.0

3. Reliability

(a) A measure of the relative improvement in the value or usage of the subject information due to changes in reliability.
(b) Score the effect on the value and use of the information of the expected changes in reliability by selecting an appropriate point on the scale given below:

	SCORE
Significantly Detrimental ----	.0
	.1
	.2
	.3
Of No Significance -----------	.4
	.5
	.6
	.7
	.8
	.9
Extremely Beneficial ---------	1.0

4. Content (New Function)

   (a) A measure of the relative improvement of the value of the subsystem's information due to new functions to be performed by the HIS application which were previously not performed.
   (b) Score the effect on the value and use of the information of the expected changes in information content by selecting an appropriate point on the scale given below:

	SCORE
Significantly Detrimental ----	.0
	.1
	.2
	.3
Of No Significance -----------	.4
	.5
	.6
	.7
	.8
	.9
Extremely Beneficial ---------	1.0

II. Indirect Considerations

A. Hospital Image

1. A measure of the expected effect of the application's successful implementation on the hospital's image (public relations, internal morale, recruitment).
2. Score the expected effect of the application's successful implementation on the hospital's image by selecting the appropriate point from the scale given below:

	SCORE
Detrimental ---------------------	.0
	.1
	.2
No Effect -----------------------	.3
	.4
	.5
	.6
	.7
	.8
	.9
Extremely Favorable -------------	1.0

IIB. Data Base Compatibility

1. A measure of the compatibility of data generated through the HIS application with the development of a management information system and data base.
2. Score the application's compatibility with and input to the development of a management information system by selecting the appropriate point on the scale given below:

	SCORE
No useful contribution to data base -	.0
	.1
	.2
	.3
	.4
	.5
	.6
	.7
	.8
	.9
Extremely useful and compatible contribution to data base --	1.0

III. Change in Operating Cost

A. A measure of the expected net change in operating costs due to successful implementation of the application.

1. Equipment, staff and overhead costs for the application.
2. Labor savings from functions to be automated.
3. Other savings or increased revenues due to reduction of lost charges and clerical errors.

B. Scoring function for change in operating cost.

Change in Annual Operating Cost	Score
$100,000	.0
80,000	.1
60,000	.2
40,000	.3
20,000	.4
0	.5
-20,000	.6
-40,000	.7
-60,000	.8
-80,000	.9
-100,000	1.0

IV. Chance for Successful Implementation

1. A measure of the probability that the candidate application will be technically sound and acceptable to staff and patients and that implementation will be successful within the anticipated period of time.
2. Score the chance of successful implementation and acceptance within the anticipated time frame by selecting the appropriate point on the scale given below:

Estimated Chance of Success (%)		SCORE
50--	Less than 50-50 chance*-----------	.0
		.1
60--		.2
	Serious Doubts-------------------	.3
70--		.4
		.5
80--	Significant Unanswered Questions--	.6
		.7
90--	Highly Probable -----------------	.8
		.9
100--	Success is certain --------------	1.0

*Prior screening should eliminate most applications with less than 50 percent chance of success.

APPENDIX D

QUESTIONNAIRE FOR EVALUATION OF THE METHODOLOGY

A. Given that a Hospital plans to implement a real-time HIS;

1. Of what significance is the setting of priorities among candidate applications to the success of the overall HIS program?
   (a) none
   (b) relatively little
   (c) moderate
   (d) great
2. The significance of HIS priority setting is derived primarily from:
   (a) technical reasons (sequence of development)
   (b) political reasons (concern over the rivalry among departments)
   (c) the desired maximization of benefits per dollar invested
   (d) other (or comments)
3. Would you recommend the use of the scoring model technique for setting implementation priorities?
   (a) No (check <u>primary</u> reasons)
      1. The technique is too complex and difficult to understand for its practical use in a hospital.
      2. The scoring model's inability to directly consider dependences among applications, variable criterion importance weightings, and other such aspects of the evaluation problem lead to biased results which are unacceptable to the hospital.
      3. Because of the great difficulties of gathering the appropriate and necessary data for use in the scoring model, the effort involved is not justified by the benefits received.
      4. Since the scoring model does not produce a directly usable implementation schedule (it must be subjectively adjusted), its results are not meaningful.
      5. Other (or comments)
   (b) Yes (check <u>primary</u> reasons)
      1. By using the scoring model-developed implementation schedule as a starting point, the planning committee can better plan the actual implementation schedule.
      2. The use of the scoring model technique sharpens the insights of the decision makers and hence leads to improved planning.

3. The scoring model technique makes the planning committee's recommendations more acceptable to the hospital staff by providing both an appearance and actuality of objectiveness.
4. The scoring model technique makes the planning committee's recommendations more acceptable to higher hospital authorities, since they are based on a logical and documented method.
5. Other (or comments)

B. Did your participation in the development and use of the scoring model for the mock hospital give you an adequate understanding of:

1. The <u>procedures</u> involved in the methodology and scoring model technique?
2. The <u>applicability</u> of the methodology and scoring model technique to HIS priority setting. (list major reasons)?

C. Do you feel that the scoring model approach has applicability in other decisions making areas in the health field?

Summary of Questionnaire Responses

Question	Alternative Responses	Number of Evaluators Responding
A1 Significance of Priority Problem	a. none	0
	b. relatively little	0
	c. moderate	1
	d. great	5
A2 Reasons for Significance	a. technical	
	b. political	1
	c. maximization of benefits	
	d. other	1
	e. a, b, and c	4
A3 Recommendation of use	a. No	1
	1. too complex	1
	2. biased results	0
	3. not justified	0
	4. not meaningful	0
	5. other	0
	b. Yes	5
	1. better schedule	1
	2. sharpens insights	5
	3. hospital staff	1
	4. higher authorities	0
	5. other	0
B Adequate understanding of:		
1. Procedures	a. no	1
	b. yes	5
2. Applicability	a. no	5
	b. yes	1
C. Other Applications	a. yes	5
	b. no	1

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